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ARCHIVES OF SURGERY

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AUTOGENOUS FREE CARTILAGE TRANSPLANTED INTO JOINTS

AN EXPERIMENTAL STUDY *

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AND
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CLEVELAND

Experimental investigation of the behavior of autogenous free cartilage in the joint space has been made difficult by the early attachment of such cartilage to the synovial membrane.

Strangeways [1] expressed the view that articular cartilage derived its nutriment from the synovial fluid and that loose cartilaginous bodies not only survived in the joint cavities, but also increased in size. Such clinical evidence led Fisher [2] at about the same time to suggest the following two possibilities referable to the nutrition of cartilage: (1) that plasma flowed into the joint from the capillaries lying in the cancellous plates abutting on the calcified layer, or (2) that plasma flowing into the joint from the plexus of vessels lying beneath the synovia at the margin of the articular cartilage was the source of this nutrition. He also believed that cartilage cells free in a joint retained their vitality in almost every case and after a time actively proliferated.

Fisher [2] studied the behavior of cartilage in joints of the rabbit by chiseling off portions of cartilage, which were freed in the joint. He stated:

> It was found in every case that the body acquired almost immediately an attachment to the synovial membrane, that the latter surrounded it with a connective tissue sheath, and that this sheath had the remarkable property of laying down new cartilage upon the surface of the original articular cartilage.

* Submitted for publication, Nov. 23, 1929.

* From the Laboratory of Surgical Research and the Department of Pathology, the Lakeside Hospital and the Western Reserve University School of Medicine.

1. Strangeways, T. S. P.: Observation on the Nutrition of Articular Cartilage, Brit. M. J. **1**:661 (May 15) 1920.

2. Fisher, A. G. T.: A Study of Loose Bodies Composed of Cartilage, or of Cartilage and Bone, Occurring in Joints; with Special Reference to Their Pathology and Etiology, Brit. J. Surg. **8**:493 (April) 1921.

Haas [3] studied the behavior of bone and cartilage transplants free in joints, hoping that by placing the fragments in a fenestrated rubber tube anchorage of the tissue to the synovial membrane might be prevented. In all of the twelve experiments, the contents of the tubes became adherent to the synovia, which defeated the primary purpose of his investigation, namely, a study of the behavior of cartilage and bone without vascularization.

We cast about for some means whereby the phenomenon of adhesion and vascularization might be prevented in order that observations could be made on the response of cartilage when nourished as nearly as possible by the synovial fluid alone. After our work was completed, Pollock, McKenney and Blaisdell [4] reported certain experimental observations on the behavior of bone transplants, having used collodion membranes in about the same manner as we did with cartilage. Unfortunately, none of their sacs remained intact. In view of these studies, as well as certain indeterminate work which has been done with cartilage cultures in vitro, we were led to believe that pieces of cartilage might be placed in some dialyzable membrane which would permit nourishment of the tissue by synovial fluid alone, without vascularization from the synovia, using at the same time a substance that would not act as a chemical irritant to the tissues.

The conclusions referable to the behavior of cartilage free in the joint space previous to this time have been largely theoretical deductions drawn from pathologic material removed from the human joint at operation or autopsy.

EXPERIMENTAL PROCEDURE

Thirteen dogs, between 4 and 8 months of age, were used for this investigation. Two pieces of cartilage were removed from the right knee and introduced into the joint cavity of the left knee of each animal.

Drop ether anesthesia was used, and the skin over the inner aspect of each knee was shaved and prepared with alcohol and mercuric chloride. The cartilage was removed by shaving the joint surface of the lateral eminence of the lower portion of the articular surface of each femur. In most instances, the entire thickness of the articular cartilage, together with a thin layer of the subchondral spongiosa, was obtained. Each specimen of cartilage was approximately 6 mm. long with a maximum width of 3 mm. The thickness varied, but averaged between 2 and 3 mm. In some of the animals only a single specimen was taken, as recorded in the protocol.

One specimen of cartilage was enclosed in a collodion sac, and as a control the other cartilage was introduced uncovered into the joint cavity.

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3. Haas, S. L.: The Transplantation of Bone into Joints, Arch. Surg. **13**:426 (Sept.) 1926.

4. Pollock, W. E.; McKenney, P. W., and Blaisdell, F. E.: The Viability of Transplanted Bone: An Experimental Study, Arch. Surg. **18**:607 (Feb.) 1929.

Collodion sacs were prepared by inserting the end of a glass tube into one half of an ordinary small gelatin capsule and dipping it into an 8 per cent solution of collodion. The collodion was allowed to dry in the air for five minutes and was then redipped. While the collodion was drying, the tube was twirled to prevent an uneven coating. Five minutes after the second dipping, the tubes were immersed in water, and the collodion-coated capsule was removed by circling the tube with a sharp knife and blowing on the open end. The gelatin was then dissolved and washed out of the sac with warm water. The sacs were stored in the refrigerator in physiologic solution of sodium chloride. Just before being used, these sacs were washed in 70 per cent alcohol and rinsed with sterile saline solution. The sac was then filled with saline solution, the sliver of cartilage inserted and the sac tied with silk, then dried and dipped in ether and the entire end, including the silk tie, smeared with collodion.

All sacs were tested for defects before being used. It was found that such a sac permitted diffusion of inorganic salts in solution, but did not allow passage of the protein molecule. The dialysate of blood serum through such a sac was found to be negative for protein or protein split products by the biuret and Heller's ring test. At the end of varying periods of time, the left knee joint of each animal was reopened, and both fragments of cartilage were removed. Each piece of cartilage, including the collodion covering of the one, was fixed in formaldehyde, sectioned serially and stained with hematoxylin and eosin.

PROTOCOLS

PROTOCOL 1.—Three specimens of cartilage were taken from the right knee of dog 1, weighing 5.4 Kg. One was fixed in formaldehyde immediately, and the other two were introduced into the cavity of the dog's left knee joint. At the end of seven days, the dog died of pneumonia. The left knee was opened; the wound had healed by first intention, and the synovia was smooth and free from inflammation. The encapsulated, as well as the unencapsulated, piece of cartilage was found to be free from adhesions, and the two lay in the posterior joint space.

Histologic Observations.—Control Specimen of Cartilage: Sections included the entire thickness of the joint cartilage with a lower margin of attached subchondral spongiosa. The cartilage had a homogeneous faintly basophilic matrix. The cells just below the articular surface were spindle-shaped and disposed parallel to the surface. Deeper in the cartilage, they were spherical and larger, and as the zone of provisional calcification was approached they showed some tendency to be arranged in columns. The cells occurred in small clusters. The nuclei were round, and the cells filled their lacunae. There was a zone around the lacunae in the deeper portion of the cartilage in which the matrix took a more deeply basophilic stain. The zone of provisional calcification was narrow and incomplete with occasional vascular loops penetrating it from the marrow. The trabeculae of the primary spongiosa were heavy and thickly disposed.

Unencapsulated Cartilage: This was removed seven days after its implantation in the left knee joint. Sections of cartilage included a narrow zone of primary spongiosa. The entire specimen was encased in a loose capsule of fibrous connective tissue. The superficial zone of cartilage showed considerable absorption of matrix with exposure of the fibrils. The exposed fibrils of the cartilage blended indistinguishably with the covering fibrous connective tissue. The disposition, number and size of cartilage cells did not appear to be changed. The articular zone of the matrix was acidophilic, and the basophilic cell areolae of the deeper cartilage were paler than those observed in the control. The zone of

provisional calcification showed no change. There were two shallow knife wounds which represented operative artefacts. These were both filled by fibrous connective tissue which appeared to be an ingrowth from the fibrous capsule of the implant.

Encapsulated Cartilage: The specimen of cartilage (fig. 1) was removed seven days after its encapsulation and implantation in the knee joint. The collodion sac appeared to be intact throughout. The surface of the cartilage showed a narrow zone of granular basophilic necrosis. There was no connective tissue covering beneath the necrotic zone. There was some absorption of matrix with exposure of the fibrils. The entire specimen showed some loss in basophilic staining properties, and there was a complete disappearance of the basophilic cell areolae. The cartilage cells showed various stages of degenerative changes, although most of them appeared normal. The degenerative changes were

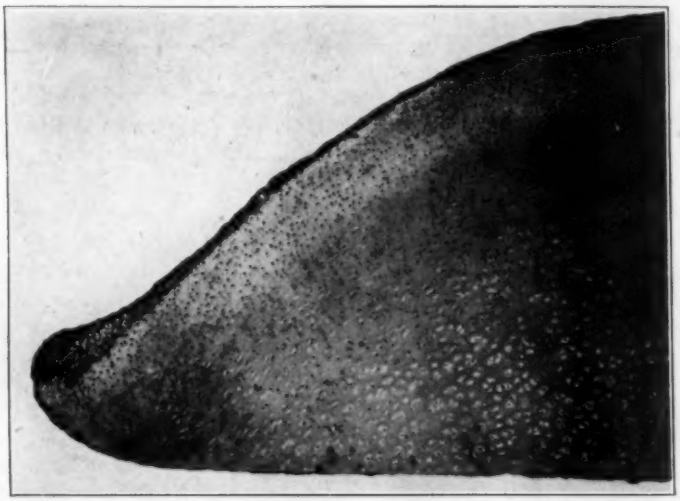

Fig. 1.—Specimen of cartilage from dog 1. The cartilage was enclosed in a collodion sac and implanted in the joint cavity for seven days. The sac remained intact.

manifested by a shrinkage of cells within their lacunae. In some instances, the nuclei were pyknotic, and a considerable number of lacunae appeared empty. The cartilage cells in the deeper layers showed no change other than a loss of cell areolae. One small knife wound in this piece of cartilage gaped and showed no healing.

Protocol 2.—Two pieces of cartilage were taken from the right knee of dog 5, weighing 6.2 Kg., and inserted into the cavity of the left knee joint. One was unencapsulated and the other was enclosed in a collodion sac. After twenty-two days, the knee joint was opened and both cartilages were removed. The encapsulated cartilage was found to be incorporated in the wound just beneath the synovia. It was firmly attached by fibrous adhesions. The unencapsulated cartilage was free in the joint space. The synovia was smooth, and there was no evidence of inflammation.

Histologic Observations.—Unencapsulated Cartilage: The unencapsulated specimen of cartilage including a portion of the subchondral osseous lamella was enclosed in a thin fibrous connective tissue capsule. The cartilage showed a superficial lacunar absorption of matrix with superficial exposure of fibrils and invasion by the surrounding fibrous connective tissue. The cells filled their lacunae and showed no degenerative changes, and the basophilic areolae were well marked. The zone of provisional calcification and underlying osseous lamella showed no change.

Encapsulated Cartilage: The collodion sac contained several small defects through which fine strands of fibrous connective tissue extended. At the ends of the specimen, the exposed fibrils merged indistinguishably with a thin layer of fibrous connective tissue which completely covered the specimen and filled in the marrow spaces between the trabeculae of the primary spongiosa. There was some diminution in the staining intensity of the cell areolae. The cartilage cells themselves showed no changes.

PROTOCOL 3.—A single piece of cartilage was taken from the right knee of dog 53, weighing 2.3 Kg. and enclosed in a collodion sac and introduced into the joint cavity of the left knee. After twenty-two days, the left knee was reopened and the encapsulated cartilage was found free in the joint cavity.

Histologic Observations.—There was no evidence of any defect in the sac. The thin ends of the specimen were the seat of granular basophilic necrosis, and the cells in the superficial layer of the cartilage showed an unusual degree of flattening, but there was no apparent absorption of matrix nor exposure of fibrils. The cartilage appeared to have shrunk. This appearance was due to the flattening of cartilage cells throughout a fairly wide peripheral zone. Deeper in the cartilage, the cells were large, spherical or biscuit-shaped, and filled their lacunae. There was some reduction in basophilic staining property, and the cell areolae was relatively pale.

PROTOCOL 4.—A piece of cartilage enclosed in a collodion sac was introduced into the cavity of the left knee of dog 33, weighing 3.5 Kg. After twenty-five days, the knee was reopened, and the encapsulated cartilage was found free in the joint space.

Histologic Observations.—The sac was intact, and the sliver of cartilage was rounded off to fit the space within the sac. The cartilage (fig. 2) appeared in an excellent state of preservation, and the basophilic cell areolae were pale and did not offer much contrast to the neutrophilic matrix. There was no evidence of fibrous connective tissue proliferation within the sac.

PROTOCOL 5.—Two specimens of cartilage were removed from the right knee of dog 4, weighing 4.1 Kg., and introduced into the left knee. After twenty-eight days, the joint was reopened, and neither the encapsulated nor the unencapsulated specimen could be identified. The joint space was distended with a viscid purulent exudate, and the synovial surface was covered with fibrinous exudate.

PROTOCOL 6.—Two pieces of cartilage were introduced into the joint cavity of the left knee of dog 99, weighing 6.2 Kg. The knee was reopened after twenty-eight days. The wound had healed by first intention. The specimen enclosed in a collodion sac was free in the joint space. The unencapsulated specimen was firmly attached to the synovia.

Histologic Observations.—Unencapsulated Cartilage: The cartilage occupied the center of a synovial projection and was covered with a thick layer of fibrous

connective tissue which showed abundant vascularization. The cartilage showed lacunar absorption of the matrix from the surface both from above and from below. There was extensive vascularization of the cartilage. The matrix, however, appeared homogeneous, and the cartilage cells showed no change. There was some loss in basophilic staining properties.

Encapsulated Cartilage: The sac was not intact, and at one end there was a narrow pedicle of fibrous connective tissue extending through a defect in the sac and becoming continuous with a thin fibrous layer that covered the cartilage. The cartilage itself appeared fibrous, and with high magnification the cells were elongated and spindle shaped.

PROTOCOL 7.—One specimen of cartilage was enclosed in a collodion sac and introduced into the joint cavity of the left knee of dog 39, weighing 5.2 Kg.

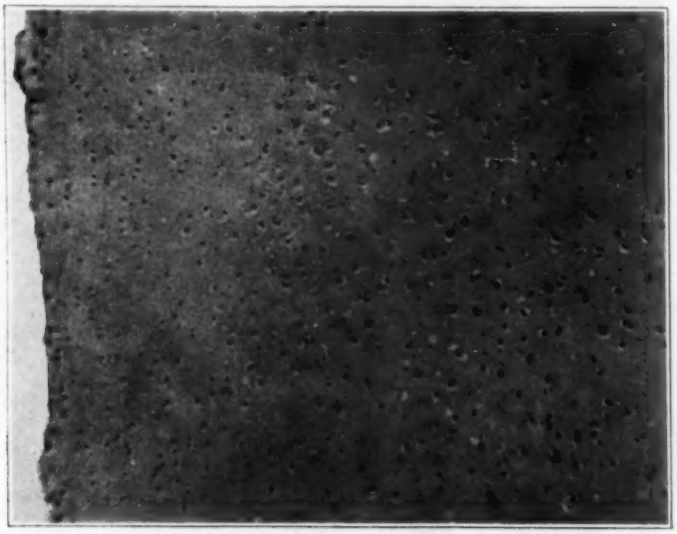

Fig. 2.—Specimen of cartilage from dog 33. The cartilage remained twenty-five days in the joint cavity and was enclosed in an intact collodion sac.

The left knee was reopened after thirty-two days. The wound had healed, but there was marked edema of the subcutaneous tissue, and the joint cavity was distended with cloudy fluid. The tip of the sac enclosing the cartilage was found to be attached to the synovia.

Histologic Observations.—There was a large defect in one end of the sac with a band of young fibrous connective tissue extending through the sac. The cartilage itself had entirely disappeared leaving only the subchondral osseous lamella and a few trabeculae of the primary spongiosa. There was a small amount of exudate within the sac consisting of polymorphonuclear leukocytes and fibrin.

PROTOCOL 8.—A single specimen of cartilage was removed from the right knee of dog 48, enclosed in a collodion sac and introduced into the joint cavity of the left knee. The joint was reopened after thirty-two days, and the encapsulated cartilage was found attached to the hypertrophic synovia.

Histologic Observations (fig. 3.)—There were several small defects in the sac through which slender bands of fibrous connective tissue extended to become continuous with a thin fibrous capsule that enclosed the cartilage. There was a slight degree of matrix absorption along the superficial surface, and the surrounding fibrous connective tissue was vascularized. The cartilage itself showed no vascularization. The cartilage cells filled their lacunae, and at the narrow ends of the specimens and for a short distance beneath the surface the lacunae were connected with one another by a system of canaliculi (figs. 3 and 4). These canaliculi were readily identified, since they took a deeper basophilic stain than the surrounding matrix. Deeper in the cartilage, the matrix was homogeneous, and there was no apparent communication between lacunae. In several slides, the canaliculi extended to the surface of the cartilage and apparently opened into the intercellular spaces of the fibrous connective tissue covering.

Fig. 3.—Specimen of cartilage from dog 48, showing a defect in the collodion sac and the formation of interlacunar canaliculi.

PROTOCOL 9.—A single specimen of cartilage was removed from dog 38, weighing 3.5 Kg., enclosed in a collodion sac and introduced into the cavity of the left knee. After thirty-two days the left knee was reopened, and the encapsulated cartilage was found free and unattached in the anterior joint space.

Histologic Observations (fig. 5).—Sections showed the sac to be intact, and the cartilage appeared to be in an excellent state of preservation. The cells were small, but filled their lacunae, except at the narrow ends of the specimen, where the lacunae appeared vesicular and either were empty or contained only a pyknotic remnant of the cartilage cell. The matrix was uniformly acidophilic, and the cellular areolae were lost. Here, as in the encapsulated specimen from dog 48, a system of canaliculi connected the lacunae. In this specimen, the canaliculi were not limited to the periphery and ends, but were seen throughout almost the entire matrix.

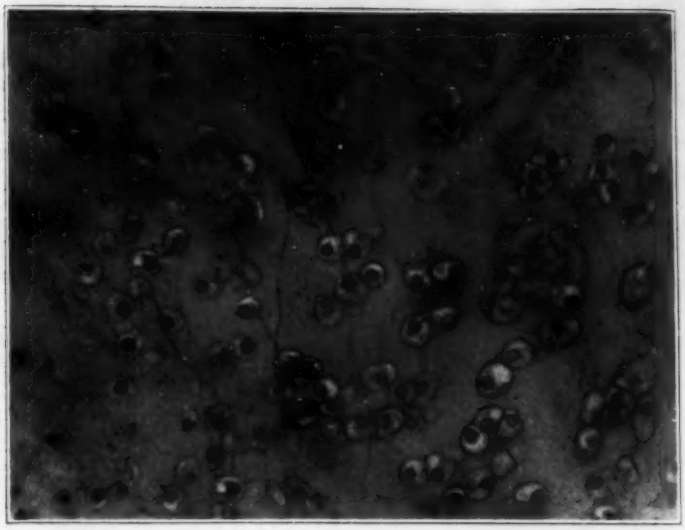

Fig. 4.—High power magnification of interlacunar canaliculi. Specimen of cartilage shown in figure 3.

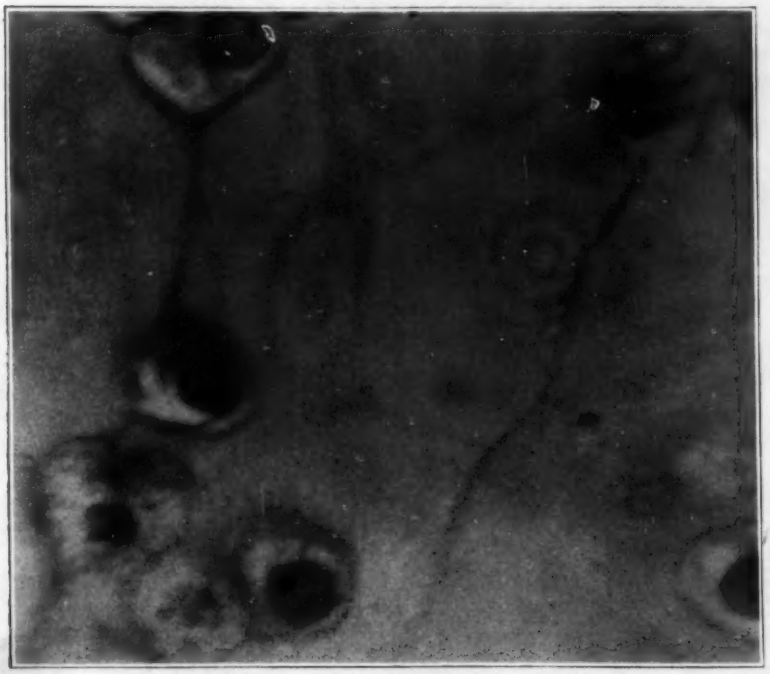

Fig. 5.—High power magnification of cartilage from dog 38 showing interlacunar canaliculi.

PROTOCOL 10.—Because of the thinness of the articular cartilage, three small shavings of cartilage were removed from the joint space of the right femur of dog 32, weighing 5.45 Kg. The fragments were all small, and were enclosed in a sac, which was introduced into the left knee. After thirty-seven days, the sac was removed. There was some excess of synovial fluid, and the synovia was covered with friable villous granulation. The sac was grossly intact and was embedded in a pocket in these granulations.

Histologic Observations.—Sections showed the subchondral spongiosa entirely denuded of cartilage. There were many small defects in the sac, which contained purulent exudate.

PROTOCOL 11.—Three pieces of cartilage were removed from the articular surface of the right femur of dog 96, weighing 7.2 Kg. One was taken for histologic examination of normal cartilage; one was introduced without covering, and the other was enclosed in a collodion sac and placed in the left knee joint. At the end of fifty-two days, the left knee was reopened and showed no evidence of inflammation. The encapsulated and nonencapsulated specimens were adherent to one another and to the synovia in the intercondylar fossa.

Histologic Observations.—Control Specimen of Cartilage: The control specimen had an appearance essentially identical with that of the control specimen described in protocol 1 (dog 1).

Unencapsulated Cartilage: The unencapsulated specimen of cartilage was surrounded by a fibrous connective tissue capsule which was continued as a vascularized pedicle from one end. The cartilage showed considerable peripheral matrix absorption and fibrous connective tissue replacement. The matrix was fibrillar rather than homogeneous, and the deeper cartilage cells appeared well preserved, and filled their lacunae, which were rounded. Toward the surface, these lacunae were elongated and disposed parallel to it.

Encapsulated Cartilage: The collodion sac had many small defects with extension of the surrounding fibrous connective tissue into the sac and around the enclosed cartilage. The cartilage was almost entirely replaced by fibrous connective tissue and showed vascularization. The lacunae throughout most of the specimen were connected with one another by small canaliculi similar to those previously described.

PROTOCOL 12.—Two pieces of cartilage were removed from dog 97, weighing 6 Kg., and one was placed in a collodion sac. Both specimens were inserted into the left knee joint. After eighty-four days, the left knee was reopened, and both specimens were found to be adherent to the synovia by fine fibrous adhesions.

Histologic Observations.—Unencapsulated Cartilage: The specimen included a generous amount of attached subchondral spongiosa. The cartilage was vascularized and enclosed in a thick cushion of fibrous connective tissue. The matrix was homogeneous and took acidophilic stain.

Encapsulated Cartilage: There were large defects in the collodion sac, and the entire specimen of cartilage was ensheathed in fibrous connective tissue, which had replaced the superficial zone of the cartilage. The matrix was homogeneous and showed a loss of basophilic staining properties. The cartilage cells appeared well preserved, and filled their lacunae. The lacunae at the ends and in the superficial portions of the cartilage were seen to be connected by a network of fine canaliculi.

PROTOCOL 13.—The articular cartilage from dog 98, weighing 7.4 Kg., was thin, and it was possible to remove only a thin sliver of cartilage, which was enclosed in a collodion sac and introduced into the cavity of the left knee. At the end of

194 days, the left knee was reopened. The joint fluid was clear, and the synovia was smooth, except at the site of the scar of the previous operation. There was no evidence of the sac or the cartilage.

COMMENT

Four of the thirteen collodion sacs introduced into the knee joints remained intact. In six sacs there were defects, and four of these six were attached to the synovia by vascularized pedicles of fibrous connective tissue while two were free in the joint cavity and showed no vascularization. In three instances, both sac and cartilage had partially or entirely disappeared in the purulent exudate within the joint cavity.

The four specimens of cartilage enclosed in sacs which remained intact were removed from the joint cavity after seven, twenty-two, twenty-five and thirty-two days, respectively. These pieces of cartilage were all well preserved and contained what appeared to be living cells (figs. 1 and 2). The contour of the cartilage had rounded and become adapted to the shape of the sac, so that there was no space between sac and cartilage. There was a narrow superficial zone in each cartilage which was acellular, and the matrix of this zone appeared finely granular and faintly basophilic. Generally, there was a loss of the basophilic staining property of the matrix, and the deeply basophilic cell areolae had entirely disappeared. The cells, for the most part, filled their lacunae and appeared unchanged. However, at the narrow ends of the specimen and for a short distance beneath the surface many of the cells had shrunk away from their lacunae, and the nuclei were in many cases pyknotic. A few lacunae were empty, and the cell had entirely disappeared. There were two essential differences between the unattached cartilage free in the joint cavity and enclosed in an intact sac and the unattached cartilage free in the joint cavity and enclosed in a defective sac that admitted the passage of whole synovial fluid. In the former, the cartilage cells appeared concentrated, as though the entire specimen had become somewhat shrunken, and yet exposure of fibrils was relatively insignificant. In the latter, varying degrees of matrix absorption had taken place, but there was no apparent shrinking or concentration of cells in the still recognizable cartilage. The other difference was the entire lack of cell proliferation within the intact sacs (figs. 1 and 2). Knife wounds in these pieces of cartilage showed no evidence of healing, and there was no capsule of fibrous connective tissue interposed between sac and cartilage. In the latter, there was proliferation of fibrous connective tissue to fill the interstices within the sac (fig. 3) and to heal the knife wounds.

In those specimens of cartilage enclosed in sacs which had not remained intact, the changes were not uniform and did not show a consistent relationship to the time during which they had remained in the joint cavity. Absorption of the matrix so that the fibrils were recognizable was fairly constant. Fibrous metaplasia of cartilage was a characteristic change and appeared to proceed from the surface in toward the subchondral osseous lamella which was in most instances attached. In the deeper portions of the cartilage, the cells were round or oval and occupied definite lacunae in a hyaline matrix. As the surface was approached, these cells were more and more elongated, and the matrix appeared more fibrillar, and the transition from cartilage to the fibrous connective tissue covering was so gradual that no sharp line of demarcation was seen. This fibrous metaplasia constituted an interesting distinction between cartilage which had survived in an intact sac and cartilage which had survived in a sac permitting free access to synovial fluid. In the former there was more "Demaskierung" but no metaplasia, while in the latter metaplasia was a characteristic change. If the change from cartilage to fibrous connective tissue is dedifferentiation, it should have occurred in both instances.

In a number of specimens of cartilage which had been in defective sacs, a fine network of interlacunar canaliculi was seen (figs. 3, 4 and 5). In some of the specimens, this system was apparent only at the narrow ends and beneath the surface, while in others the entire piece of cartilage was traversed by the canaliculi. They extended between the cell lacunae and also communicated with the surface.

Such a system of interlacunar canaliculi has been observed in the cartilage of various of the invertebrates. Dahlgren and Kepner [5] noted that in the cartilage of squid and other invertebrates there is a system of communicating passages between cell lacunae through which cytoplasmic processes of the cells extend. These cell processes they believe provide for the passage of food and other materials. Cajal is cited by Bailey [6] as having observed a system of fine white lines connecting the cells of the costal cartilage of young dogs. Hammar [7] stated that he observed unquestionable interlacunar communication only in the superficial zone of the articular cartilage, and although many investigators have reported the finding of interlacunar passages, he was unable to determine whether they are preformed or artefact.

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Solger [8] observed this structural character of hyaline cartilage and believed it to be an artefact of fixation. Wolters [9] believed the communication to be preformed. Several conditions led us to the opinion that these canaliculi were actual and not artefact. The manner in which they widened and became funicular as they approached cell lacunae did not appear consistent with the conception of artefact (fig. 5). Under low magnification, this system of canaliculi appeared to form an intercommunicating network (fig. 3), but with high magnification it was seen that the canaliculi did not communicate with one another, except through cell lacunae (fig. 5). They extended between single cartilage cells or groups of cells and occasionally reached the surface. Their distribution bore no relation to the long axis of the fibrils (fig. 3), and if their appearance was due to dehydration and shrinkage we should expect that there would have been a definite relationship between the long axis of the interlacunar channels and the direction of the matrix fibrils.

In no instance was this canalicular system seen in normal joint cartilage, nor was it seen constantly in the specimens of cartilage enclosed in collodion sacs. It seems entirely possible that the patency of the canaliculi depended on the degree of elasticity of the matrix and that they became visible incidental to matrix absorption. That matrix absorption occurred was indicated by the concentration of cartilage cells.

SUMMARY

Articular cartilage will survive as long as thirty-two days, nourished only by the diffusible elements of the synovial fluid. Unattached, nonvascularized cartilage in direct contact with synovial fluid shows superficial fibrous connective tissue proliferation, while cartilage enclosed in a collodion sac and accessible only to the diffusible elements of the synovial fluid shows no cell proliferation. The demonstration of fibrous connective tissue proliferation in unattached, nonvascularized tissue in the joint space offers an explanation for the spontaneous production of and accretion to joint-mice. A system of interlacunar canaliculi adequate to provide for circulation of fluids in the matrix of articular cartilage is demonstrated.

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THE CAUSE OF DEATH IN UNCOMPLICATED HIGH INTESTINAL OBSTRUCTION

EXPERIMENTAL EVIDENCE TO SHOW THAT DEATH IS DUE NOT TO TOXEMIA, BUT TO LOSS OF DIGESTIVE FLUIDS AND SALTS *

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AND
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The cause of death in all types of intestinal obstruction has been so long and so unanimously ascribed to toxemia that the work of a small group who maintain that toxemia is not important in simple high occlusion has been rather generally disregarded. This group comprises the following investigators:

1. Hartwell and Hoguet,[1] who in 1912 first called attention to the life-saving properties of salt solution. They believed that its physiologic effect was in the prevention of the dehydration, which they considered to be the chief lethal factor.

2. Gamble and McIver,[2] who believed that in these cases death is due primarily to the loss of the electrolytes sodium and chlorine, with secondary inability of the tissues to maintain their normal fluid content.

3. White and Bridge,[3] who pointed out that since salt is lost from all the viscera, muscles and skin, as well as from the blood, by vomiting, the chloride ion cannot have the toxin-neutralizing effect ascribed to it by Haden and Orr [4] and other recent writers, e. g., Phillips and Stowe.[5]

* Submitted for publication, Dec. 9, 1929.

* From the Surgical Services, Massachusetts General Hospital, and the Surgical Research Laboratories, Harvard Medical School.

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2. Gamble, J. L., and McIver, M. A.: Body Fluid Changes Due to Upper Intestinal Obstruction, J. A. M. A. **91**:1589 (Nov. 24) 1928.

3. White, J. C., and Bridge, E. M.: Loss of Chloride and Water from the Tissues and Blood in Acute High Intestinal Obstruction, Boston M. & S. J. **196**: 893 (June 2) 1927.

4. Haden, R. L., and Orr, T. G.: The Effect of Sodium Chloride on the Chemical Changes in the Blood of the Dog After Pyloric and Intestinal Obstruction, J. Exper. Med. **38**:55 (July) 1923. These investigators now believe that the neutralization theory is untenable, but they still claim that toxemia is the important factor in causing death in this type of case (Chemical Factors in the Toxemia of Intestinal Obstruction, J. A. M. A. **91**:1529 [Nov. 17] 1928).

5. Phillips, K., and Stowe, W. P.: Intestinal Obstruction and Septic Invasion of the Peritoneum, Arch. Int. Med. **44**:543 (Oct.) 1929.

4. Wilkie,[6] who in 1913 wrote: "Simple obstruction of the intestinal lumen must be clearly distinguished from strangulation." He pointed out further, that when an obstruction was placed between the upper secretory part of the intestine and the lower absorptive part, the resulting condition was due to loss of the vomited secretions, and not so much, if at all, to toxemia.

More recently, Foster and Hausler,[7] as well as Gatch, Trussler and Ayres,[8] divided intestinal obstruction into two main groups: (1) simple occlusion of the lumen of the upper small intestine without interference with its blood supply—no toxemia; (2) "strangulation obstruction," with impairment of circulation, in which toxemia is marked, as shown by physiologic and biochemical experiments.

One of us (J. C. W.[9]) reported further experimental and clinical evidence in support of the classification. In the first group, toxemia is not important if the occlusion is high enough for the obstructed bowel to empty itself freely by vomiting, since then it does not become distended to the point of losing its normal blood supply. In such cases, as Wilkie [6] showed, even if toxins are present in the obstructed contents, they are not absorbed by the normal intestinal mucosa to any appreciable extent.[10] Life can be prolonged many days in these cases simply by the replacement of sodium chloride and water. However, if the loss of these substances in the obstructed secretions is not compensated, experimental animals and human beings die when the chlorides of the blood and tissue have fallen to about half their normal level.

The chloride recovered from the vomitus and from the contents of the obstructed gastro-intestinal tract at autopsy corresponds fairly closely to that lost from the tissues and blood of the entire organism. We have verified this in a large number of dogs, cats and human beings.

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6. Wilkie, D. P. D.: Experimental Observations on the Cause of Death in Acute Intestinal Obstruction, Brit. M. J. **2**:1064 (Oct. 25) 1913.

7. Foster, W. C., and Hausler, R. W.: Studies of Acute Intestinal Obstruction, Arch. Int. Med. **34**:697 (Nov.) 1924.

8. Gatch, W. D.; Trussler, H. M., and Ayres, K. D.: Causes of Death in Acute Intestinal Obstruction, Surg. Gynec. Obst. **46**:332 (March) 1928.

9. White, J. C.: Recherches expérimentales et cliniques sur le mécanisme de la mort dans l'occlusion intestinale aïgue, Lyon chir. **25**:622 (Sept.-Oct.) 1928.

10. Wangensteen and Chunn proved that all intestinal contents, even after sterilization by Berkefeld filtration, are toxic when injected intravenously. This is the case regardless of whether the material is taken from a normal dog, from above or below a simple occlusion or from a closed loop. (A Comparison of the Toxicity of Normal and Obstructed Intestinal Content, Arch. Surg. **16**:607 [Feb.] 1928).

Gamble and McIver,[2] as well as Atchley and Benedict,[11] published similar results.

The second group may be expanded to include all intestinal obstructions accompanied by impaired blood supply, whether this impairment is due to strangulation, mesenteric thrombosis, volvulus, intussusception or simple obstruction with distention. This group carries a far more serious prognosis. Kader [12] in 1892 and Murphy and Vincent [13] in 1911 first showed that interference with the intestinal blood supply (particularly on the venous side) is a vital factor governing the severity of symptoms in acute obstruction.

McIver and White [14] found that cats with experimental volvulus of a section of the middle of the small intestine, 20 cm. long, died in about twenty hours, whereas with simple division and inversion of the bowel ends at the same level, animals survived from three to five days. Since the animals died rapidly, vomiting in the group showing "strangulation" was slight or absent. Consequently, the reduction in the chlorides of the blood and tissue was correspondingly small. The only procedure capable of prolonging life, short of resection of the strangulated gut, was the removal of the strangulated gut to the outside of the abdominal wall. This evidently prevented the absorption of toxins, and completely altered the pictures. Two animals treated in this way lived three and five days, vomited profusely and died when they had lost half the chloride of the body. In other words, an obstruction of the second type was converted into one of the first.

The evidence in favor of death by absorption of toxins in the second group is overwhelming. Practically all experimental and clinical observers are agreed on this. Therefore, the discussion at the present moment concerns the first group. The experimental work reviewed makes a fairly strong case against the importance of toxemia when the mucosa has its normal blood supply. If a potent toxin is being absorbed, it is difficult to see how salt solution could sustain life in these cases, since it has no appreciable effect in combating the toxemia in the "strangulation" group.

It occurred to us that the toxemia theory in the simple high obstructions would be rendered even more untenable if an animal with such

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11. Atchley, D. W., and Benedict, E. M.: The Distribution of Electrolytes in Intestinal Obstruction, J. Biol. Chem. **75**:697 (Dec.) 1927.

12. Kader, B.: Ein experimenteller Beitrag zur Frage des localen Meteorismus bei Darmocclusion, Deutsche Ztschr. f. Chir. **33**:214, 1892.

13. Murphy, F. T., and Vincent, B.: An Experimental Study of the Cause of Death in Acute Intestinal Obstruction, Boston M. & S. J. **165**:684 (Nov. 2) 1911.

14. McIver, M. A., and White, J. C.: The Rôle of the Bacillus Welchii in Acute Intestinal Obstruction, Ann. Surg. **89**:647 (May) 1929.

a condition could be kept alive over a considerable period simply by restoring the materials lost in the vomitus through an ileostomy below the point of obstruction. In such an event, it would be illogical to believe that the obstructed contents contain any important absorbable toxin. Furthermore, if no additional salt were given, it also would be impossible to claim that toxins in the tissues are neutralized by an excess of chloride ion.

EXPERIMENT

Technic.—In order to test this, we operated on a police-dog bitch weighing 14.0 kilograms, under ether anesthesia, and severed the small intestine 12 inches (30.48 cm.) below the pylorus. The two ends were invaginated and buried separately in the omentum. A no. 20 soft rubber catheter was then inserted obliquely (by the Witzel method) into the distal small intestine. The catheter was brought out through the omentum, then through a separate stab wound in the left rectus muscle, and firmly secured by a broad bandage of adhesive tape. The perineum was split toward the rectum, so that the urethral orifice could be seen and the bladder catheterized.

The animal made an excellent operative recovery. It was kept in a cage for use in the study of metabolism, so that the vomitus could be collected, and the animal was catheterized twice daily to prevent contamination of the vomitus with urine. Later, the dog learned to void while outside the cage on a leash. Formed stools were caught on a wire grating, so that fecal contamination occurred only when the dog developed a watery diarrhea. It was given all the water that it would drink.

Three or four times each day all the vomitus, diluted to 200 cc. with water, was injected through the catheter into the lower unobstructed small intestine. After three days, we added as much dextrose as the intestine would tolerate, as we wished to prevent a ketosis and to maintain the animal's nutrition as well as possible on a completely salt-free diet. Dextrose, of course, had no effect on the process in question, as Haden and Orr [4] have shown that it does not prolong life in intestinal obstruction.

We were unable to keep up the animal's caloric requirements by dextrose without producing a troublesome watery diarrhea; therefore, it slowly but steadily lost weight. After two weeks, we tried adding small amounts of "Casec," which is a proprietary infant food and is nearly all protein with less than 1 per cent of ash. This was not completely digested, presumably on account of the lack of protein-splitting ferments in the lower bowel.

Observations.—Table 1 gives the complete record of the dog's intake and output and also its condition from day to day.

In spite of the total high obstruction, the dog remained in surprisingly good condition for the entire month. During this period it remained bright and active, playing with other dogs in the laboratory and jumping in and out of the cage (which was 2½ feet [30 cm.] from the floor) through the first fortnight. During the second two weeks, the partial starvation weakened the dog somewhat. The weight sank slowly, but progressively, from 14 to 10 Kg. Nevertheless, the animal remained as bright and alert as at the beginning of the experiment.

The chemical changes in the blood and tissues are shown in table 2. There was essentially no change in the plasma bicarbonate and nonprotein nitrogen throughout the entire month. The chloride fell slowly to 410 mg. in the blood plasma and to correspondingly low levels in

TABLE 1.—*Data on Metabolism*

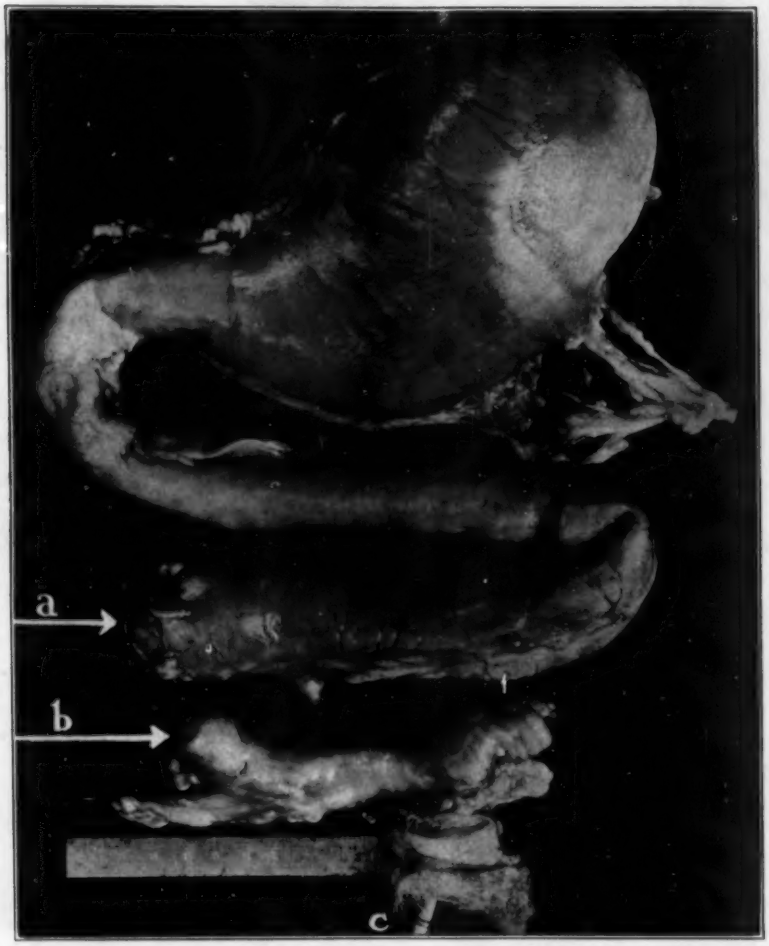
Days After Operation	Output: Vomitus, Cc.	Output: Urine, Cc.	Output: Stool, Gm.	Output: Nacl, Gm.	Intake: Nacl, Gm.	Intake: Mouth, Cc.	Intake: Ileum, Cc.	Weight, Kg.	Comments
1	.....	700	...	.....	...	500	550	14.00	Good operative recovery
2	Trace	900	...	Trace	...	.....	400	.....	
3	500	500	...	2.1+	2.1	200	500	.....	Dog in good condition
4	500	580	70	2.0+	2.0	1,000	780	13.80	
5	580	220	500	2.4+	2.4	1,000	750	.....	From this point on, 75 Gm. of dextrose (average dose) was injected daily through ileostomy
6	1,430	325	500	7.1+	5.2	1,000	1,400	.....	
7	170	1,130	...	0.7+	0.7	1,000	1,200	13.10	Dog active
8	900	900	620	3.5+	3.5	1,000	1,000	.....	
9	190	680	...	Trace	...	1,000	1,190	12.50	
10	300	940	Trace	.....	...	1,000	950	.....	Slightly lethargic
11	600	580	...	3.4+	3.4	500	850	.....	
12	.....	400	400	.....	...	1,000	900	12.20	Bright and active again
13	.....	240	750	.....	...	1,000	1,200	.....	
14	345	120	...	1.1+	...	500	900	12.00	A little weak, as she lies down when left alone
15	250	442 (mixed)		1.2+	1.2	500	1,200	.....	
16	.....	1,250 (mixed)		.....	...	.....	900	11.80	
17	.....	1,320 (mixed)		.....	...	500	1,200	.....	
18	.....	810 (mixed)		.....	...	.....	1,200	11.50	During second half of experiment 25 Gm. of "Casec" (average) was injected daily through ileostomy
19	.....	1,380 (mixed)		.....	...	500	1,150	.....	
20	.....	1,000 (mixed)		.....	...	.....	950	11.45	
21	.....	600 Trace		.....	...	680	1,270	.....	Again active
22	.....	1,000 (mixed)		.....	...	1,000	1,200	.....	Dog beginning to weaken and fairly emaciated; mentally, bright and interested in surroundings
23	260	500	100	1.5+	1.5	500	950	.....	
24	20	400	100	Trace	Trace	500	1,200	10.60	
25	100	500	200	0.6+	0.6	500	1,200	.....	
26	.....	1,480 (mixed)		.....	...	.....	1,150	.....	Dog lies down, but walks about when taken out of cage
27	.....	820	...	.....	...	260	900	.....	
28	.....	825	...	.....	...	.....	.....	10.00	Dog killed; autopsy

TABLE 2.—*Chemical Data*

Days After Operation	Tissues: Skin Cl., Mg.	Tissues: Muscle Cl., Mg.	Blood: Chloride, Mg.	Blood: Nonprotein Nitrogen, Mg.	Blood: CO_2, per Cent
Before operation.	380*	190*	650*	30*	56.0*
3	...	...	599	33	....
9	...	...	535	..	....
11	...	...	474	24	58.2
18	...	...	440	..	57.6
21	...	...	...	..	56.0
28	215	101	410	33	63.2

* Preoperative figures are based on average normal values. Chlorides are expressed as milligrams of sodium chloride per hundred grams of tissue or plasma; nonprotein nitrogen in milligrams per hundred cubic centimeters of plasma, and carbon dioxide in volumes per cent of the plasma.

the muscles and skin. In untreated dogs, vomiting as much as this one did, a similar reduction would have taken place in from three to five days. The slow loss of chloride, which for the month amounted to about 40 per cent, can be accounted for in the small daily loss of vomitus



Postmortem specimen showing stomach with dilated obstructed duodenum above; *a*, obstructed upper segment showing complete occlusion by inversion of the jejunum. Below distal unobstructed segment of the upper ileum with catheter inserted obliquely through the skin and abdominal wall. *b* indicates the inverted proximal end of the lower collapsed segment; *c*, the catheter enterostomy.

and in the diarrheal stools. When these were mixed with vomitus they were reinjected through the ileostomy; but when recovered pure or mixed with urine they were rejected. No appreciable elimination

occurred through the urine after the third day (it is well known that as the blood chloride level falls the kidneys stop secreting salt).

At the end of a month, the dog, although somewhat weak from the prolonged low intake of food (it received on the average 250 calories a day, which amounted to only 50 per cent of the calculated maintenance diet), appeared to be in good health and did not give the impression of being dehydrated or extremely emaciated. But as we did not wish to subject the animal to unnecessary suffering and felt that a month was sufficient to demonstrate that life could be maintained by restoring the substances lost in the vomitus, it was killed by the administration of ether on the twenty-eighth day of the obstruction. Autopsy showed that the obstruction had remained complete, and revealed no other gross abnormalities (fig.).

COMMENT

By this experiment, we have demonstrated that an animal with a total obstruction of the upper small intestine can be kept alive and in good health as long as the loss of digestive secretions is prevented and the nutrition maintained. We are not urging this as a therapeutic panacea, since both animals and human beings with this type of obstruction do so well with injections of physiologic solution of sodium chloride. Whether the biliary, pancreatic and gastroduodenal secretions contain other substances vital to life besides sodium chloride is beyond the scope of this paper. But this animal remained in much better condition with the restoration of its own vomitus and lived much longer than any which we treated with injections of salt and dextrose.

The point we wish to bring out is the absence of toxemia in this type of obstruction. The presence of absorbable toxic substances in the dammed-up gastro-intestinal contents is inconceivable when it was through their injection that life was preserved. It is equally inconsistent to claim that hypothetic toxins in the body can be neutralized by the chloride radical, when no extraneous salt was given and its content in both the blood and the tissues was considerably reduced during the experiment.

In our experimental animals and in a large number of patients with this type of obstruction who have been studied in the Massachusetts General Hospital, the same generalized dechlorination—tissues $\xrightarrow{Cl}$ blood $\xrightarrow{Cl}$ vomitus—invariably has occurred. Tables 1 and 2 show that this process has taken place slowly here. With it there has been no corresponding rise of nonprotein nitrogen or increase in the excretion of nitrogen by the kidneys, which one would expect if a proteolytic toxin were being absorbed. To reinforce our argument from another angle, it may be pointed out that in the group showing "strangulation," in which toxemia is profound, there often is a normal chloride level in the blood and injections of salt solution are not of the slightest use

in preventing the rise in nonprotein nitrogen or in combating the toxemia.[15]

Experimental evidence in the papers cited points strongly to dehydration as the cause of the nitrogen retention in the simple high obstructions. It is most surprising that this animal did not become dehydrated, as during the course of the month we were unable to prevent a considerable loss of blood base, as well as chloride. (The blood base fell from a normal of 160 cc. of 0.1 normal base per hundred cubic centimeters of serum to 131 cc.) It is beyond the scope of this paper to go into the physiology of the acid-base equilibrium and its application to this case; but it is probable, on account of the gradual depletion of sodium and chloride, that the organism was able to compensate for the loss of electrolyte and to maintain the water content of its tissues in some unknown way.

In this connection, it is interesting to note that the dog was able to absorb as much as a liter (1,000 cc.) of water a day through the upper 12 inches (30.48 cm.) of the small intestine. After the first week of the experiment, the dog began to adjust itself to the new conditions by vomiting less and less. Thus, during the first week, it vomited 3,180 cc.; during the second, 2,335 cc.; during the third, 250 cc., and during the fourth 380 cc.

Since this experiment was performed, we have read the paper of Raine and Perry.[16] They showed that when a rabbit is given a simple jejunal obstruction, death follows in from twenty to thirty hours. As the rabbit is unable to vomit, all the obstructed secretion remains in the dilated stomach and duodenum. When the obstruction is released just before the animal is moribund, the obstructed secretions pass down the intestine and are absorbed, and the animal's condition rapidly improves. The removal of the stomach contents and their replacement by distilled water, before the obstruction is removed, greatly retards recovery. This experiment showed in another way that no potent toxin is absorbed in simple high obstruction, and that it is the loss of the digestive secretions that causes death.

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15. It must not be forgotten, however, that most cases of human intestinal obstruction are mixtures of the two types; a volvulus or an intussusception occludes the lumen of the intestine, as well as shuts off its blood supply. Therefore, if these patients live long enough, they usually vomit and dechlorinate to a certain extent. They may even secrete a considerable quantity of chloride into the obstructed gastro-intestinal tract without vomiting. For this reason, in every case of intestinal obstruction salt solution should be used, although its effect in the second group is slight in comparison with that in the first.

16. Raine, F., and Perry, M. C.: Intestinal Obstruction: Experimental Studies on Toxicity, Intra-Intestinal Pressure and Chloride Therapy, Arch. Surg. **19**:478 (Sept.) 1929.

CONCLUSIONS

1. A dog with a complete high intestinal obstruction was kept alive and in good condition for a month. This was accomplished by preventing the loss of its digestive secretions, these being immediately reinjected into the lower unobstructed bowel.

2. It is extremely unlikely that any potent toxin formed in the obstructed intestine can be absorbed by the mucous membrane as long as its blood supply is maintained; otherwise, life would have been shortened rather than prolonged by the reinjection of the obstructed secretions.

3. The theory that the beneficial effect of salt solution is due to the neutralization of toxin by the chloride radical seems illogical. This animal received no salt from outside sources and became considerably dechlorinated during the prolonged obstruction, owing to a small, unavoidable daily loss. The dechlorination of the tissues corresponded to that of the blood.

4. As the nonprotein nitrogen and nitrogen output in the urine remained normal, there is no evidence that tissue protein was destroyed by toxin.

5. We believe that death in the uncomplicated high obstructions is due mainly to loss of salt and water, possibly also to other substances, in the gastroduodenal secretions. When inorganic electrolytes are lost rapidly and are not replaced, it becomes impossible for the organism to retain its normal water content. This leads to fatal changes in the physiochemical equilibrium of the blood and tissues.

NOTE.—While this article was in press, Dr. W. H. Snyder and one of us (J. C. W.) repeated these observations on a second dog. This animal was given a complete obstruction at the same level and was observed over a period of two weeks. During this time the dog received only its vomited digestive secretions plus water and dextrose, which we injected through an enterostomy in the upper end of the distal small intestine. The animal reacted in every way like the one in the experiment reported, remaining in excellent condition except for a similar slow fall in blood chloride and body weight. There was again no evidence of toxemia or dehydration. The absence of dehydration was noticed clinically in the first dog, but in the second it was confirmed by laboratory tests as well. There was no increase in the plasma protein nor any appreciable change in the erythrocyte count or the hematocrit reading.

TUMORS OF THE ORBIT*

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NEW ORLEANS

In this paper I report four types of tumor of the orbit with which I have had personal experience: (1) osteoma of the orbit, (2) epithelioma of the lids and of the bridge of the nose, (3) carcinoma of the lacrimal gland and (4) melanoma.

In some of these cases exenteration was required, and in one all the manifestations were relieved by removal of the primary growth.

They are included in a single report because of the following facts: All the growths involved either the walls of the orbit or its contents. In some instances the growths involved the orbital contents other than the globe. This happened in the malignant cases which began primarily as epitheliomas of the lid and the bridge of the nose or as carcinoma of the maxillary antrum. In these cases the growths began outside the orbit and later involved its contents.

In some instances there were manifestations of disturbance of vision from encroachment on the orbital contents and consequent displacement of the eye itself. In some instances exenteration was necessary in spite of the fact that there was no invasion of the globe, and because radical removal of the growth would have left the eye without proper protective covering.

In one of the cases which excited a great deal of interest, the growth seemed to have originated within the globe, either as a melanoma or as a glioma of the retina. It destroyed the eye so completely that in the gross specimen it was difficult to identify the various structures of the eye.

There were two osteomas of the orbit, on only one of which I operated. This I believe to have been a fronto-orbital osteoma.

OSTEOMA OF THE ORBIT

The two cases cited represent the only bony tumors of the orbit I have had occasion to see. The apparent rarity of the condition excited my interest, and after a search of the literature it seemed worth while to report them because so far as I can find there are not more than 250 cases recorded.

It will not be necessary to review the literature extensively. The first case was recorded by Veigas in 1506 (Bedell). Andrews, in 1887,

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collected reports of all the cases that he could find up to that time. He reported sixty which had been already recorded and forty-eight for which he found records among 429,989 cases of disease of the eye which had been observed in the New York Hospital from 1821 to 1887.

William F. Smith reviewed the literature again in 1888. In 1904, Le Grange found 148 cases. Culbert, in 1918, found records of 215 cases from 1748 to 1918.

The subject of orbito-ethmoidal osteomas (a selected group from within the larger group) was considered by Dr. Cushing of sufficient importance to be made the subject of his presidential address before the American Surgical Association. In this address he recorded four cases which had come under his observation. Cushing stated that Dr. A. S. McMillian of the Massachusetts Eye and Ear Infirmary had seen only one of these lesions after an experience of 15,000 examinations of roentgenograms of sinuses.

In reviewing the cases which have been reported one finds confusion, particularly with reference to the origin of these tumors. It would seem worth while to classify all bone tumors found within the orbit as orbital osteomas and under this general heading to have subdivisions that would indicate their point of origin and the etiology.

Cumston, in 1920, gave a definition that should satisfactorily meet this demand. He said: "Osteomata of the orbit are bony growths which reproduce all varieties of bone tissue taking their origin in the walls of the orbit itself or in the neighboring cavities, such as the ethmoidal cells, nasal fossae, antrum of Highmore and more frequently of all the frontal sinus." This definition permits the inclusion of exostoses in the term osteomas.

Virchow, discussing the origin of these tumors, stated:

> Although there is scarcely any part of the orbit where these bone tumors have not been found the upper and inner part, however, are by far the most frequent sites. It is understandable how difficult it may be to determine whether a tumor has originated primarily in the nasal or frontal sinuses or in the orbital cavity; whether it comes from the inner or outer surface of the bone; finally whether it originated from the frontal or ethmoid bone or somewhere else. For all these possibilities there is evidence in the literature, without it being always possible to determine the correctness of either opinion. For a tumor which arises from the interior of the frontal bone can very well later on project into the frontal, orbital, nasal or cranial cavity.

Cushing, in 1927, was prompted to say:

> Whence may well be asked does the original tumor arise and what is the significance of its apparent relation to a preceding injury? Doubtless mild frontal injuries may more often than suspected produce a fissured fracture of the thin floor of the anterior cranial fossa, if not a fracture of diastasis. It is not inconceivable that some quiescent cartilaginous anlage may have been stimulated to bone productive activity.

Birch-Hirschfeld, in 1906, differentiated between the encapsulated osteoma and an exostosis. The encapsulated osteoma he found had a tendency to grow toward the brain. These tumors arise in accessory nasal cavities and then extend into the orbit. In the exostoses there is a history of trauma, and they usually arise from the upper inner orbital walls and grow out into the orbit.

William F. Smith as early as 1888 said:

> There are three points or characteristics which should distinguish osteomata from exostoses. They are (1) the origin of the tumor from one of the bony cavities; (2) the encapsulating membrane, and (3) the ivory hardness. The osteoma rarely, if ever, has a traumatic origin; the exostoses nearly always have a history of trauma and are developed from the periosteum.

GENERAL OBSERVATIONS

Age.—Bony tumors within the orbit are found largely among young people. According to Culbert, 50 per cent occur during adolescence and 30 per cent more before the patients reach the age of 30.

Location.—The tumors may be located at any point within the orbit, but the most common site is the upper inner wall. They may take their origin from the frontal bone, the frontal sinus, the ethmoid bone or from periosteomas.

According to Gerber, "the proportion of tumors arising within the ethmoid is as 12 to 8 to those arising in the frontal sinus." In osteomas of the frontal sinus the largest proportion of the growth is in the sinus and only a small part, according to Lebensohn, projects into the orbit.

Osteomas of the frontal sinus perforate the walls of the sinus and enter the orbital cavity; they may perforate into the cranial cavity. The latter is a point of great importance and one which has been particularly emphasized by Cushing as an indication for a cranial approach rather than an intra-orbital approach.

Period of Development.—Osteomas are slow growing. In many instances several years elapse before they produce sufficient annoyance to cause the patient to seek relief.

The size of these growths varies. In the earlier literature, there are records of cases in which the growths attained "the size of a child's head." In one instance, the tumor measured "7½ inches in circumference and 2¾ inches in thickness."

DIAGNOSIS

Prior to the use of the roentgen ray, the diagnosis could be made certain only at operation. Because of the great service which the roentgen ray renders, cases that could not otherwise be diagnosed are now found, and in some instances these growths have been found in the

course of an examination of the sinuses when no suspicion of their existence had been aroused in the mind of the surgeon.

There are few outspoken manifestations. However, a number of signs and symptoms have been found sometimes in association and sometimes independently. Little pain is associated with some of them. There may be severe headache, which is usually intermittent rather than continuous.

Cumston stated that there may be a neuralgic pain which is transmitted along the fifth cranial nerve. Diplopia is sometimes present but has not been a constant manifestation. The globe may be dislocated in varying degrees. Exophthalmos of varying degrees is the most constant manifestation. If dislocation takes place it is very slow and, according to Gerber, the direction of the dislocation gives an idea of the location of the tumor. He says, "When the protrusion is exceedingly outwards a tumor of the ethmoid is inferred; where the globe is directed upwards the maxillary sinus is involved, while a propulsion forwards, outwards and downwards is pathognomonic for tumors of the frontal sinus."

A visual disturbance, according to Cumston, is often related to the exophthalmos. He further says that the "displacement of the eye is necessarily accompanied by traction on the nerve, which, combined with the pressure exercised by the growth, brings about changes in the fundus, usually phenomena of stasis; a more or less marked coloring of the papilla due to engorgement of the veins; arterial anemia or even ischemia resulting from compression or the return circulation."

In this connection it is interesting to note that in spite of the indolent nature of the growth it has been said that removal of the tumor sometimes results in considerable improvement of vision.

Negative evidence is sometimes as valuable as positive evidence. There is one negative observation that has aroused the interest of observers, particularly that of Cushing, who called attention to the absence of rhinologic symptoms in spite of the association of these growths with the paranasal sinuses.

It will be noted by reference to case 1 here reported that there was no evidence of disturbance of the various sinuses.

PROGNOSIS

These growths are histologically benign, but because of the effect produced by pressure, Lebensohn has properly remarked that they are clinically malignant. When one considers the complications in patients who are not operated on, such as exophthalmos, optic neuritis, optic atrophy, sinus infection, perforation of the roof of the orbit into the cranium with a tendency to cerebral compression, one can readily under-

stand the danger of allowing these growths to remain in an unoperated condition.

According to Birch-Hirschfeld's statement in 1907, the mortality is as follows: in those originating in the "frontal sinus without operation 48.2 per cent, after operation 13.6 per cent; ethmoid 80.0 per cent without operation, after operation 12.7 per cent; sphenoid without operation 100.0 per cent, after operation 33.0 per cent." No further plea need be made for operation.

The method of approach most commonly used has been through the orbit by an incision such as is described in this paper. Cushing advocates a cranial approach in orbito-ethmoidal osteomas. He considers either a nasal or an orbital route "awkward" because "neither method of approach makes allowance for the possibility that the tumor may have extended into the intracranial chamber."

REPORT OF CASES OF OSTEOMA OF THE ORBIT

CASE 1.—L. R., a man, aged 35, with intra-orbital osteoma, was referred for consultation by Dr. A. R. Crebbin, an ophthalmologist. The following is a brief summary of the history as taken from the record:

The patient was admitted to the Touro Infirmary on Sept. 11, 1928, complaining of pain over the eye. The left eye had begun to swell five years before. The swelling remained for three days and then subsided. The patient had had no further trouble until two weeks before. During the past five years he had had frequent headaches, the pain being greatest over the left eye. At times nausea had been associated with the headaches. There was no history of nasal trouble, and the sight had been good. Dr. Crebbin reported no pertinent symptoms of the eyes; vision in both eyes was normal and the fundi were normal. The Wassermann reaction was negative.

Prior to the time that I saw the patient, a roentgenogram had been taken of the skull. Dr. Henderson reported the presence of a large osteoma occupying the area from the superior boundary of the maxillary sinus up to and involving the frontal plate of the skull over the frontal sinus. This likewise extended as far backward as almost to come in contact with the anterior boundary of the sphenoid, thus occupying the major portion of that area normally occupied by ethmoid cells. The point of attachment and origin could not be definitely determined. However, its densest portion was its lowest segment and as it approached the frontal sinus and sphenoid, it could be seen to thin down. This was a fairly large osteoma which had many points of contact with and origin from the surrounding structures.

On September 14, I was called to see the patient and noted the following conditions:

The axis of the left eye as well as the palpebral fissure was almost 30 degrees above the horizontal axis of the right. There was fulness at the inner canthus of the left eye. No prominent bony masses were noted over the maxilla. There was a hard bony prominence which impinged on the orbit at the inner canthus of the left eye.

Dr. Weil was requested to examine the nose and throat. He reported moderate deflection of the septum to the right but sufficient breathing space. The nose was

otherwise normal. There was no apparent bulging of the ethmoid wall or any encroachment of the nose by the osteoma.

After consideration of Dr. Weil's report and the roentgenograms, it was decided to approach the intra-orbital tumor directly through the orbit, displacing the orbital contents.

An incision was made along the supra-orbital ridge and the inner side of the nasal bone, mesial to the inner canthus, and then prolonged obliquely downward and parallel to the infra-orbital ridge. The original incision was carried down to the bone. Bleeding was controlled by pressure and clamps.

The periosteum was reflected, and retractors were introduced into the orbit so as to retract the orbital contents. When this was done, a large bony mass was seen closely approximated to the nasal and lacrimal bones; the greater portion of

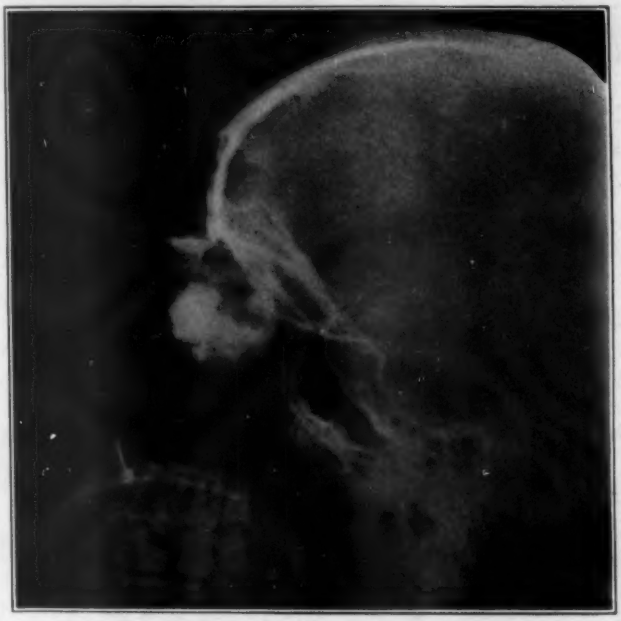

Fig. 1 (case 1).—Appearance of orbital osteoma before operation

it was free, occupying the nasal third of the orbit. The mass had a number of "bosses" on its surface. It seemed to lie under the overhanging edge of the nasal and lacrimal bones. The inner aspect of it and the lower surface were not adherent to the nasal side of the orbit. The only point of fixation was its attachment, the frontal bone. With the chisel the overhanging portion of the nasal and lacrimal bones with the inner margin of the infra-orbital ridge, or nasal portion of the maxilla, were chiseled away. The chisel was used partially to detach it from the nasal portion of the frontal bone. A grooved director could then be inserted between the perpendicular plate of the ethmoid and the growth, as well as at the base of the orbit.

With a pair of bone holding forceps the growth was grasped. It may be noted here that the forceps had to be taken apart and applied very much as obstetric forceps are applied. After the forceps were on, it was possible to remove the growth without injuring the eye or any of the contents of the orbit. There

was no active bleeding. A pack was introduced for a few seconds until the field was clear. When the pack was removed, it was seen that the growth had not invaded other structures.

There was apparently no communication between the nose and the orbit. There was no opening into the antrum. The impression that I gained at this time was that the growth had increased the size of the orbit and had not invaded the ethmoid, but had rather displaced the perpendicular plate of the ethmoid to the nasal side, thus compressing or obliterating the ethmoid sinus.

A gauze pack was introduced into the cavity and petrolatum strips were applied over the eye. Before putting the bandage on, I noted that there was no conjunctival or subconjunctival hemorrhage. The two pupils were of the same size.

Fig. 2 (case 1).—Appearance of skull after operative removal of the orbital osteoma.

The postoperative diagnosis was intra-orbital osteoma.

Following the operation, there was no disturbance of the eye. The patient left the hospital on September 30, eleven days after the operation.

Before he was discharged, however, a roentgenogram was taken, on which Dr. Henderson reported as follows: The area in which a large osteoma had been previously observed was clear; the ethmoid cells had been destroyed on this side but their walls near the outer margins were intact. Apparently all of the tumor had been removed, and the residual structures were considered to be normal.

On Dec. 1, 1929, the patient had perfect movement of the eye. There had been no evidence of an epiphora and no disturbance that would indicate injury to the orbital contents.

This case is of interest for many reasons: 1. The only disturbance produced by the tumor was pain over the eye and repeated headaches. 2. At no time did the patient complain of diplopia. 3. Examination

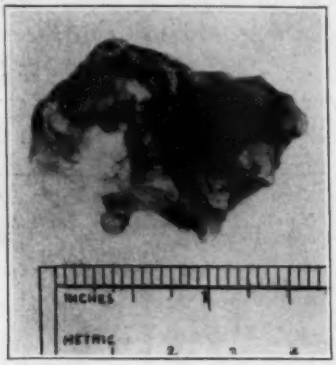

Fig. 3 (case 1).—Osteoma removed from orbit.

Fig. 4 (case 1).—Appearance of patient more than a year after the removal of the orbital osteoma.

revealed the absence of exophthalmos and the only distortion was a change in the axis of the eye. 4. There was no history of trauma and yet the growth did not seem to have its origin in any of the sinuses, the

only attachment being to the under surface of the frontal bone. 5. The entire tumor was within the orbit and not within any of the sinuses. This last fact is of importance because the majority of so-called exostoses have been associated with a history of an injury and the osteomas which have sprung from the various sinuses are found to extend from the sinus into the orbit. 6. When one considers the great size of this bony tumor surprise must be felt that it did not cause some disturbance of vision, particularly diplopia. 7. The approach through the orbit and

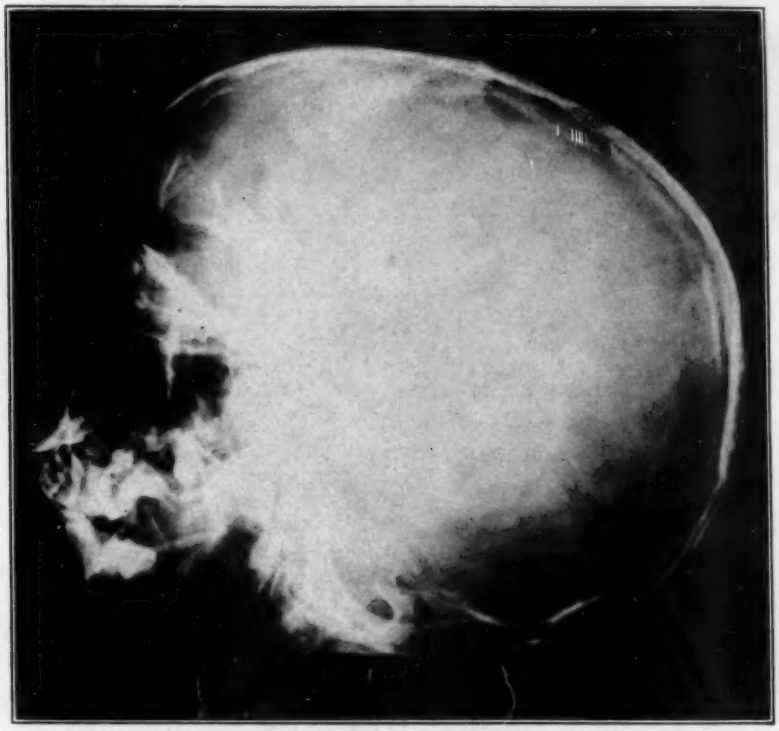

Fig. 5 (case 2).—Orbital osteoma probably springing from the wing of the sphenoid in a boy aged 13.

the displacement of its contents laterally permitted a comparatively easy removal of the entire growth. 8. The cavity from which the growth was removed was packed, because it was feared that possibly an infection of the orbit might take place from the nose, as it was not unlikely that some of the ethmoid cells might have been opened.

Since the operation the patient has had no limitation of motion of the eye in any direction, indicating that there had been no disturbance of the muscles within the orbit.

A second case of orbital osteoma springing from the wing of the sphenoid has been observed. The location of the tumor has not been

proved by operation and the case will therefore be only briefly reported in this paper.

CASE 2.—W. B., a boy, aged 13, was referred to the clinic by Dr. A. R. Crebbin of the department of ophthalmology. When he was 3 years old he had a "fever" of unknown origin. The family stated that during this attack a red spot appeared over the left eye. The child was under the care of an ophthalmologist for many months. A complete history could not be obtained. When he was admitted to the hospital, Dr. Crebbin observed that the left eye protruded forward about

Fig. 6 (case 2).—Orbital osteoma.

one-third to one-half inch more than the right. There was a more or less irregular conical cornea with degenerative changes in the upper third of the cornea. The entire eye was enlarged and protruded (buphthalmos), though the corneal dimensions themselves showed little or no increase. The lower lid did not show any abnormality but the upper lid was retracted back into the orbit by some type of adhesion at the junction of the outer quarter with the inner three quarters. Below this was a mass covered with conjunctiva, about the size of a white bean, which was somewhat compressed and moved somewhat as the eye or lower lid moved. The conjunctiva over this was red and brawny, as was the conjunctiva in the upper portion of the eyeball. This was from exposure to the air caused by the fixed

upper lid. The anterior chamber was fairly deep as a result of the conical shape of the cornea. The pupil was centrally placed and reacted well in accommodation to light. So far no view of the fundus had been obtained.

On April 17, 1928, a roentgenogram was taken, on which Dr. Henderson reported as follows: On the left side there was a dense clouding of the osseous tissue which did not, however, involve the antrum on that side; the walls of a somewhat nodular tumor were very well outlined involving the orbit. The structural changes seen were considered to have been produced by a benign tumor of the osteoma type, rather than a malignant growth.

Dr. Weil found no evidence of involvement of the sinuses.

On examination, April 19, I observed a mild proptosis of the left eye, with recession of the upper lid, particularly the outer half, and a bulging of the palpebral conjunctiva. Examination of the rest of the eye had already been made. Retraction of the mandible was apparently greater on the left than on the right side. There was no evidence of facial paralysis. The lower central incisors were at least half an inch posterior to the upper incisors. The patient was able to separate his teeth, which were markedly irregular. The soft tissue about both cheeks was not infiltrated. There was no pain or fulness over either zygoma or temporal fossa. When the patient opened his mouth, contraction of the depressors of the jaw could be seen. There was no apparent movement of the temporomandibular articulation. The diagnosis was ankylosis of the left temporomandibular articulation and osteoma of the orbit.

Roentgenograms of both temporomandibular joints were suggested to determine whether the ankylosis was unilateral or bilateral. Operation was advised.

On April 19, a roentgenogram was taken. On the right side the temporomandibular articulation was identifiable, although there was some atrophy in the ramus of the mandible. On the left side the temporomandibular articulation was completely wiped out and there appeared to be a well defined union.

From the clinical examination and the roentgen observations it was concluded that the child had an intra-orbital osteoma and an ankylosis of the temporomandibular articulation.

The parents refused to consent to operative removal of the osteoma. They were anxious to have plastic operations on the lids for the protection of the cornea. These operations were done, but as they are not pertinent to the subject no further reference will be made to them.

EPITHELIOMA OF THE LID (SQUAMOUS CELL TYPE)

The cases of epithelioma of the lid under discussion are those which required eventual exenteration.

There is no need to review the literature, as this has been done many times. A particularly valuable review can be found in the "American Encyclopedia of Ophthalmology."

All forms of treatment have been used and advised in the handling of these cases. Those patients whom I have observed had had a lesion for a long time. All had been subjected to various forms of treatment, including irradiation with the roentgen ray and radium.

Certain observations have been made in all my cases, and my experience does not seem to differ from that recorded in the literature. These growths are slow in development and recur frequently, and unless

radical procedures are adopted they extend into the orbit without affecting the globe. Metastasis to the glands of the neck is a late manifestation. They may and often do erode the bony parts of the orbit, particularly the supra-orbital plate. When this occurs the frontal lobe may be seen in the orbit. Late metastasis to the brain occurs. At times there is erosion of the ethmoid and involvement of the ethmoidal sinus.

There is considerable difference of opinion with reference to the best method of treatment for these cases. Desiccation is preferred by Clark and Weyth. In 1914 Clark said: "After excision of epitheliomas of the canthi, no matter how thoroughly the work appears to have been done, there is a percentage of recurrence. In such cases if excision is practiced a second or third operation results in exposure of the eyeball, notwithstanding the best plastic work. This is not true of desiccation." He stated further *"that operative surgery is efficient if performed radically, but the cosmetic results leave much to be desired.* Secondary plastic operations often improve this condition, but more often fail. The best argument against operative surgery in the treatment of these lesions is the fact that cases are being continually referred for other treatment by the highest exponents of the art of ophthalmic and general surgery."

I have used surgical excision, with immediate plastic repair, and endothermy or surgical excision without immediate repair. Radium has been used as a routine in the after-care. All measures have been disappointing.

One of the cases (case 5) may be cited to illustrate the method of treatment and the end-results. The patient, a man, aged 65, first came under observation in 1923. He was subjected to several operations over a period of four years in an effort to effect cure without exenteration.

This case presented an opportunity to watch the results of wide excision and plastic surgery, both of which were of no avail. A recurrence finally necessitated exenteration.

It might be well to digress a little to discuss this experience in detail. The growth involved the major portion of the lower lid, the external canthus and a small portion of the upper lid. After wide excision of the growth, the defect to be closed was great. In an attempt at repair it was necessary to observe those fundamental principles of plastic surgery so well outlined by Gillies, Blair, Davis and others: particularly to replace not only skin but supporting structures, such as the tarsal cartilage, and to avoid the embarrassment of having hair-bearing skin as part of the transplanted skin.

In my effort to replace the lower lid, a pedunculated graft was taken from the temporal region and a piece of cartilage was taken from the ear. In this instance skin was used to replace the palpebral con-

junctiva. We used this in spite of the fact that Gillies in his monograph stated that he had used it only when an artificial eye had been implanted. The skin did not act as an irritant to the eye.

In Buedinger's operation skin is also used to replace the palpebral conjunctiva. R. E. Wright described the operation as follows:

> Briefly it consists in removal of the lower lid and its conjunctiva by two incisions starting at the canthi and meeting on the cheek below. The triangular skin defect thus produced is made good by carrying a horizontal incision from the outer canthus for a distance somewhat parallel to the other side of the triangle. The flap thus defined is dissected up with its superior side in the position originally occupied by the free edge of the lower lid. Before anchoring it, however, the tarsus and conjunctiva are replaced by a composite flap from the back of the ear. This consists of semilunar pieces of skin and cartilage, still attached to each other, and having a common straight edge somewhat shorter than the edge of the cheek flap. The skin is approximately three quarters of a circle, the cartilage one quarter. This flap is applied to the deep surface of the skin flap from the cheek, straight edge to straight edge, the surface epithelium of the ear skin towards the globe. It is held in this position by two or three double-armed sutures which are passed from behind forward a short distance below the free edge, and tied externally on beads. The triangular bare area on the cheek is filled in by a graft as soon as possible.

Cartilage from the ear forms an ideal replacement for a lost tarsus.

This is not the place to discuss the relative value of any two operative procedures, nor is it my desire to do so. It can be said, however, for the procedure used in this particular case that the lid formed by the plastic operation served its purpose for a period of about four years. In the interim, however, the patient developed recurrences that necessitated operative procedures for the removal of the new growths.

In spite of all efforts it was necessary to exenterate the orbit in April, 1927, as the growth had by this time caused so much exposure of the conjunctiva that the patient was showing evidence of infection and ulceration of the cornea.

It should be stated that the lid made by the plastic operation, during the time that it remained, was sufficiently under the control of the patient so that the cornea was almost completely covered when he attempted to close the eye.

GENERAL OBSERVATIONS

Recurrences in epitheliomas of the lid appear in or near the site of the previous lesion in spite of wide excision and plastic surgery. These recurrences necessitate operative procedures which eventually expose the conjunctiva and cornea to such an extent that irritation and infection inevitably follow. When this happens, there is no alternative; the orbit must be exenterated. Enucleation is not sufficient, as the disease often has extended into the tissue about the eye, even though no disturbance

of vision exists. This is especially true if the growth has its origin on the nose near the inner canthus. Extension of the growth into the orbit is the rule in this group.

At times exenteration seems unnecessarily radical, because the patient has an eye that is useful; yet when the orbit is invaded surgically, granulomatous masses are found which in some instances have already invaded the ethmoid, antrum and even the cranial cavity.

In the after-care of these cases radium has been used as a routine.

It is surprising how quickly the large defects produced by the exenteration become filled and are covered by apparent normal epithelium. The duration of life after exenteration is surprisingly long, in some instances from three to four years.

A brief summary of the three cases of squamous cell epitheliomas in which exenteration was necessary is appended.

REPORT OF CASES OF SQUAMOUS CELL EPITHELIOMA

CASE 3.—Mrs. L. P. D., aged 60, seen in September, 1921, had first noticed a mole on the nose in 1912. The mass increased in size and extended to the eyelids. Radium was used by the physician in attendance. In September, 1921, an irregular ulcer was found on the bridge of the nose. The lids were edematous. The conjunctiva was injected and a growth extended over the upper portion of the cornea. The preauricular and digastric glands were palpably enlarged. The patient was referred to me by Dr. C. Jeff Miller and Dr. H. N. Blum, an ophthalmologist. An exeneration was done on Sept. 9, 1921, and a radium pack was introduced. The pathologist reported "squamous cell carcinoma."

On April 17, 1922, the patient presented herself again as she had a recurrence. The tumor was excised with a cautery, and radium was applied. During 1922 she had a second recurrence, for which a second cauterization was done, followed by high voltage roentgen therapy. Pain was conspicuously absent. The antrum became involved.

The patient survived at least one year longer. She lived about 100 miles from New Orleans and no autopsy could be obtained.

CASE 4.—T. M., a man, aged 64, was seen on May 28, 1929, with a diagnosis of epithelioma of the nose and lids, hypertension and arteriosclerosis. About eight months before the patient had noticed a small pimple on his nose which he squeezed. Later an ulcer on the surface was noticed. The growth gradually enlarged. There had been no disturbance of vision. Examination at that time showed an ulcerative area on the bridge of the nose. The growth extended down to the inner canthus. The edges of the ulcer were elevated and there was induration of the surrounding skin. A report from Dr. Weil, otolaryngologist, was to the effect that there was no evidence of a pathologic condition within the nose. A roentgenogram was negative for bone changes in or about the nasal structures.

A preliminary operation was done under local anesthesia. The area to be excised was circumscribed by minute punctures with the d'Arnsonval current. The incision resembled a three leaf clover, the middle leaf corresponding to the interorbital portion of the forehead and the lateral leaves extending down on the left side to the inner third of the upper and lower lids through their entire thickness and on the right side to the inner canthus. The base line swept over the nose,

Fig. 7 (case 3).—Section of squamous cell carcinoma removed from the lid.

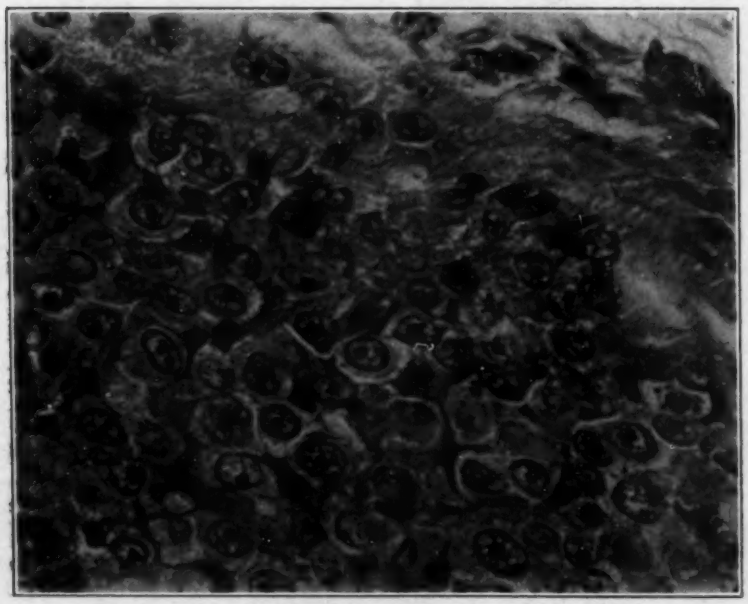

Fig. 8 (case 3).—High power view of squamous cell carcinoma.

just about half an inch from the tip of the nose at the lower limit of the cartilage. When skin was reflected from the right to the left, part of the base of the growth which covered and involved the nasal bone did not come away with the growth.

After entire removal of the flap, care was taken that the nasal bones were covered by a granulomatous mass, and then the question arose whether to attempt to remove the nasal bones entirely and exenterate the orbit. It seemed to me that removal of the nasal bone would leave too much risk of immediate infection, possibly meningitis. I used the current for the purpose of destroying all of the growth that I could see, after which 50 mg. of radium in copper was laid directly on the main portion of the nasal bone. The eyes were protected by a lead screen and 2 inches of gauze.

Following the operation, the radium pack was left in situ. The pathologic diagnosis was squamous cell carcinoma (Lanford).

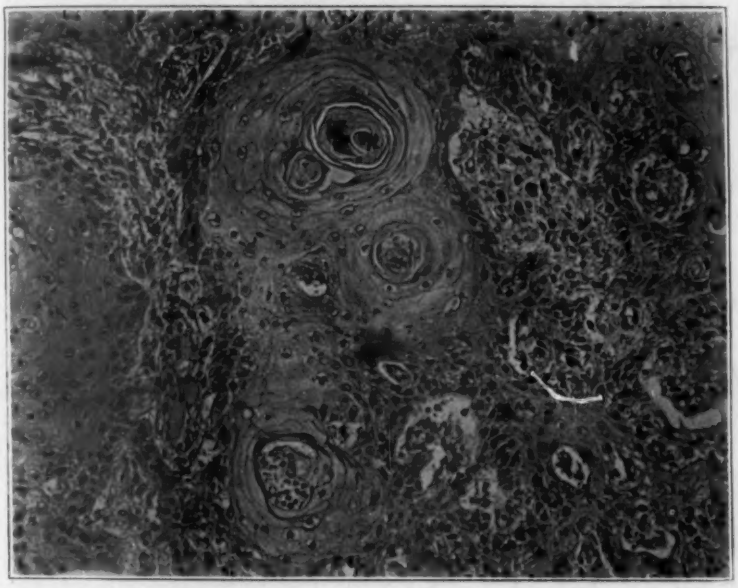

Fig. 9 (case 4).—Low power view of squamous cell carcinoma involving the nose and eyelids.

The patient was discharged from the hospital on June 12. He was readmitted on June 29. At that time a large ulcerated area was observed over the forehead and the root of the nose, extending from about 1 inch above the level of the supra-orbital ridge down to and covering the bridge of the nose. It was about 2 inches long and 1 inch wide. The ulcer involved the inner canthus of the left eye and extended to about one-half inch from the inner canthus of the right eye. It was covered by a grayish exudate. At the junction of the root of the nose and the frontal bone there was an area about three-fourths inch in diameter in which the bony tissue was exposed. The ulcer extended to the border of the left orbit. The conjunctiva of the left eye was pulled down and away from the eyeball by the contraction of the scar tissue. The conjunctiva of this eye appeared red and was inflamed; there was a free flow of tears as a result of irritation of the conjunctiva. About 1 cm. lateral to the margin of the ulcer on the left side there was a small mass situated beneath the conjunctiva. This suggested a distorted caruncle.

Because of the contraction of the scar tissue from the healing ulcer the normal anatomic arrangement was destroyed. The upper lid on the left was edematous and inflamed.

There was a small elevated area on the skin about 1 cm. in diameter situated just to the right of the lower end of the nose. This appeared to be another epithelioma.

Because apparently all of the growth had not been removed, the patient and his family were advised that it would probably be to his best interest to have the orbit exenterated in spite of the fact that it would be necessary in so doing to destroy a useful eye. Accordingly an exenteration was done on July 8. Examination of specimen by the pathologist revealed the fact that the eye itself showed no evidence of neoplasm.

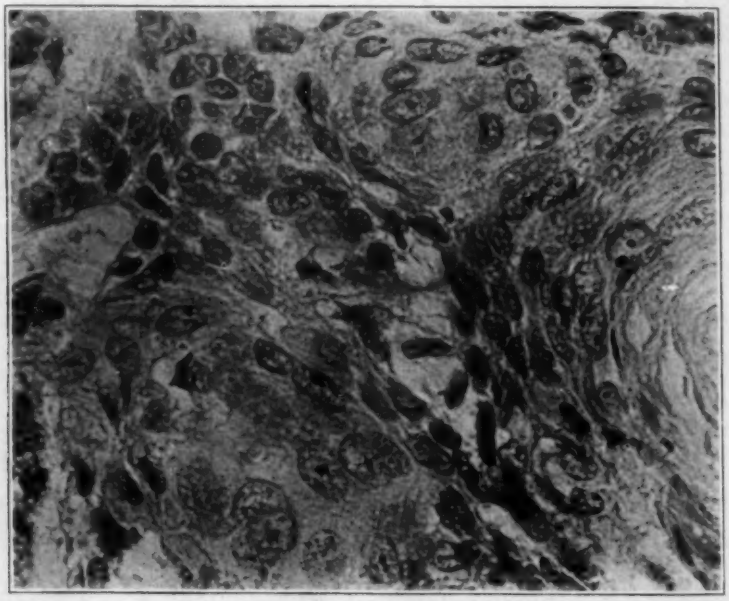

Fig. 10 (case 4).—High power magnification of squamous cell carcinoma.

In these two cases it will be noted that (1) the growth first noticed was a small mass on the nose; (2) the mass later ulcerated and involved the structures of the lid about the inner canthus and in neither case was there any disturbance of vision; (3) at operation the orbital structures, other than the eye itself, were involved; (4) both the patients were conspicuously free from pain.

Case 5.—A. D., a man, aged 65, first noticed a small growth of the outer canthus five or six years before he came under observation. His chief complaint was that it was causing a deformity of the lower lid. A mass was found on the lower lid at the external canthus. The mass was elevated and consisted of hard ulcer on the surface. The growth had invaded the upper lid at the angle and it involved a greater portion of the lower lid. There was an ectropion deformity of the lower lid and a thickening of the palperbral conjunctiva.

The first operation was done on June 1, 1923, under local anesthesia. It consisted in excision of a portion of the upper lid and the entire lower lid. A pedunculated flap was taken from the temporal region and a small piece of cartilage was taken from the helix of the ear. This was implanted in that portion of the graft which was to be used to replace the lower lid. A tubular graft was made out of the major portion of it and the palpebral conjunctiva was thus replaced by skin. The tarsal cartilage was replaced by cartilage from the ear.

The pathologic diagnosis was squamous cell carcinoma.

A number of subsequent operations had to be done in order to complete the plastic repair of the external canthus and to overcome the ectropion deformity which developed. After a time the patient had sufficient control over the lid to

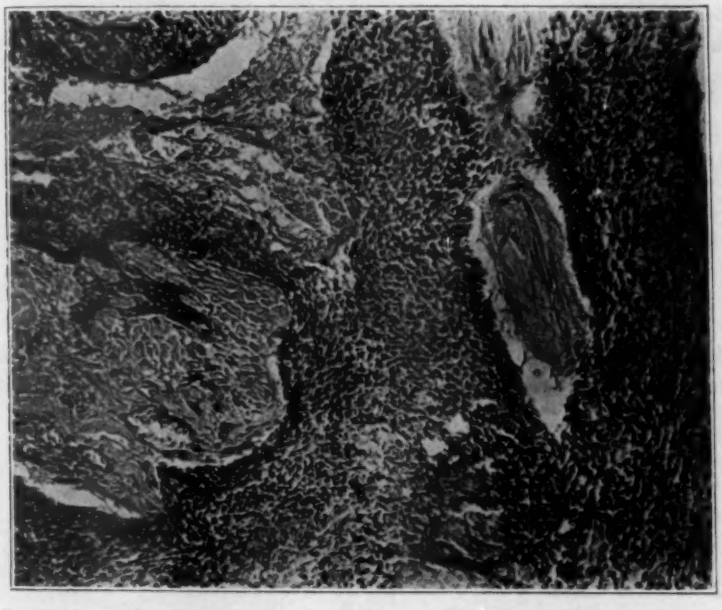

Fig. 11 (case 5).—Low power view of squamous cell carcinoma removed from the lower lid and part of the upper lid.

cover the eyeball almost completely when he attempted to close the eye. Recurrences developed one and one-half years later and from time to time it was necessary to excise recurring growths, until finally four years later it was necessary to do an exenteration.

During the whole time the patient's general condition remained excellent, and he did not complain of pain. Glands in the digastric triangle did not become involved. The patient survived the operation by more than one year. The cause of death assigned was chronic myocarditis and chronic nephritis.

1. Squamous cell carcinomas of the lid may appear at any portion of the lids. 2. They are slow growing tumors. 3. They recur frequently, metastasize slowly and eventually invade the orbit. 4. After

surgical excision, plastic surgery may save the eye for several years. 5. Eventual exenteration is as a rule necessary because of recurrences. 6. Whether radium, the roentgen ray or endothermy is better than surgery, alone or in combination, probably is hard to determine because the more radical the measure, the better will be the end-results. 7. Disturbance of vision is the exception, resulting in my experience only after there had been an exposure of the cornea. 8. Surgical intervention alone or surgical measures combined with endothermy, high voltage roentgen therapy or radium has not resulted in a permanent cure in a single case in my experience. Early treatment should give better results.

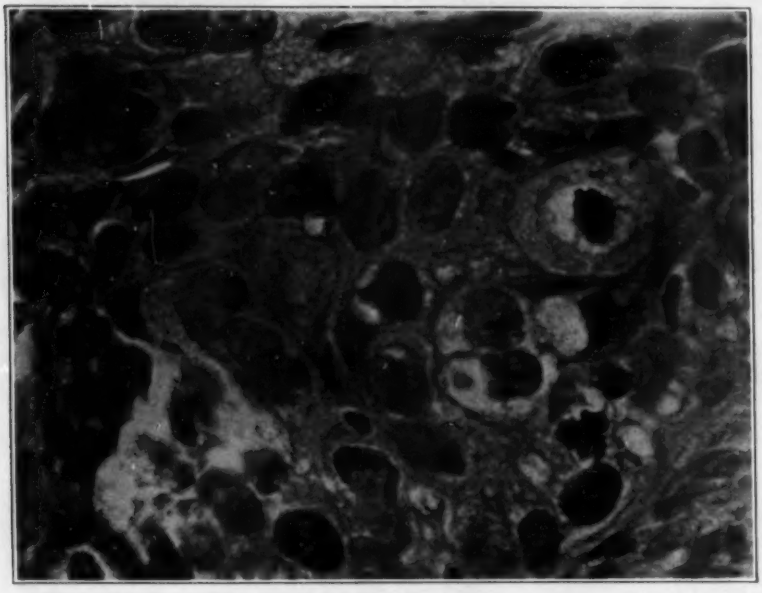

Fig. 12 (case 5).—High power magnification of squamous cell carcinoma.

CARCINOMA OF THE LACRIMAL GLAND

One of my cases belongs in this group. The clinical observations may be summarized as follows:

CASE 6.—Mrs. B., aged 45, complained of pain in the orbit of three years' duration. The severity of the pain was progressive; there was loss of vision, progressive exophthalmos and ptosis. At no time could an ulcerating lesion be found. The sinuses were normal. The Wassermann reactions of the blood and spinal fluid were negative. Several doses of arsphenamine did not benefit the patient, and she was referred for operation by Dr. H. N. Blum.

Exenteration revealed the fact that the globe was not affected, but there was a large soft mass above and posterior to the eye. The supra-orbital plate had been eroded by the growth. The frontal lobe could be seen in the orbit.

Radium and a pack were introduced into the cavity.

The pathologist returned a report of epithelioma from a section examined immediately, and later stated that the tumor was a carcinoma of the lacrimal gland (figs. 13 and 14).

The patient lived nearly four years. During the last few months of her life there was evidence of recurrence, the new growth apparently being located in the brain, as the patient had violent headaches, with projectile vomiting followed by symptoms of meningitis and death.

This history and course are characteristic of carcinoma of the lacrimal gland.

According to the literature, carcinomas of the orbit rarely if ever occur as a primary growth except as an extension from a lacrimal gland. Secondary tumors, as illustrated by the previous group, may involve the

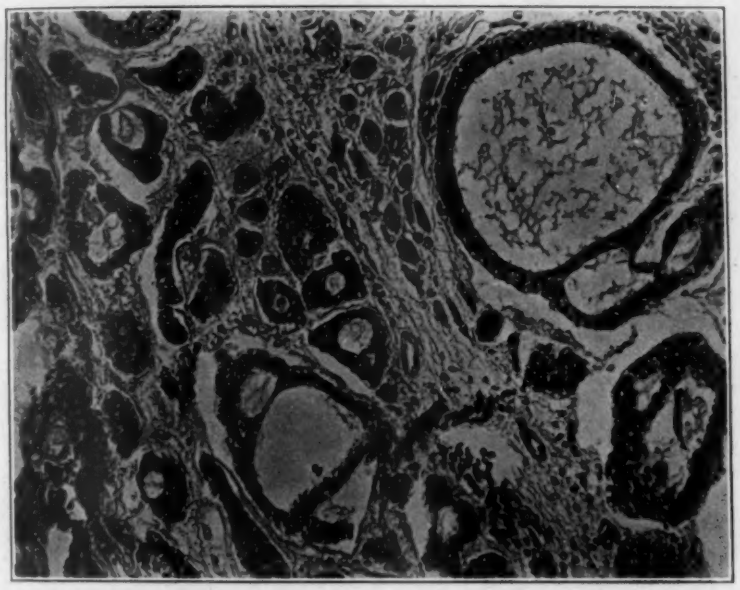

Fig. 13 (case 6).—Section of carcinoma of the lacrimal gland seen in the low power field.

orbit in connection with new growths of the conjunctiva or other tissues of the lid. These extend inward and may fill the whole orbit. The prognosis is always grave, and the treatment, especially in carcinoma secondary to that of the lacrimal gland, is essentially surgical—exenteration of the orbital contents.

MALIGNANT TUMOR OF THE ORBIT ASSOCIATED WITH METASTASES: MELANOMA OF THE OBRIT

The case of melanoma of the orbit here reported was striking in its clinical aspect and proved to be of even greater interest from an anatomic and histopathologic standpoint.

CASE 7.—A, a man, aged 73, admitted on June 11, 1928, to the service of Dr. Blum, ophthalmologist, was referred for consultation with the following history: the patient was struck on the left eye by a bolt about ten years ago. Two years ago a growth began in the upper lid and this steadily increased in size. At times the growth was painful. He had lost 30 pounds (13.6 Kg.) during the past three months.

On examination, I found a mass occupying the left orbit and part of the left cheek; it extended one-half inch anterior to the nose. The upper lid was stretched and entirely covered the bulb. The lower lid had been stretched by a mass from behind so as to expose the palpebral conjunctiva completely. The veins were much distended. The lids were almost purple. There was no ulceration of either lid. Near the inner canthus was a sinus which I took to be the lower canaliculus. The mass that occupied the orbit was fixed to the underlying structures but not to the skin; it was not painful to the touch. The cervical glands were not enlarged.

Fig. 14 (case 6).—High power magnification of carcinoma of the lacrimal gland.

Stereoscopic pictures did not show evidence of increased vascularization of the skull. Exenteration was advised.

The roentgenologic report was that there was no evidence of bony tumor to be observed about the eye, and from the roentgenographic standpoint no other evidence could be observed than a large soft tissue mass occupying the orbital region (fig. 16).

Dr. Heninger of the medical service reported hypertension, heart disease, arthritis and arteriosclerosis associated with chronic nephritis.

Dr. Rosen reported that the auricular rate was 72; the ventricular, 72; the auriculoventricular interval, 0.16 second, and the Q-S interval, 0.07 second. There was sinus rhythm. No electrocardiographic evidence of myocardial disease was apparent.

Operation was performed on June 1, 1928. The tumor was circumscribed. The skin over the frontal bone, above the supra-orbital ridge, was retracted, as was the cheek below the infra-orbital ridge. As soon as this had been done, I was able

Fig. 15 (case 7).—Appearance of patient with melanoma of the orbit.

Fig. 16 (case 7).—Roentgenogram of the skull, showing melanoma of the orbit.

to cut some of the muscular attachments which allowed mobilization of the orbital tumor.

At this stage I realized that it was necessary to section the malar portion of the orbit, and this was done with a ronguer. About an inch of the external orbital rim was removed. The orbital tumor was mobilized, and the optic nerve and ophthalmic artery were sectioned. The tumor was removed, and a pack was introduced into the depths. At this stage, I saw that the orbital plate had been eroded and a portion of the frontal lobe of the brain could be seen in the upper portion of the wound.

The ophthalmic artery was ligated; the other vessels in the wound were transfixed. An iodoform gauze pack soaked in compound tincture of benzoin was introduced into the depths and three dermal sutures were used to make certain that the pack would remain in situ (fig. 17).

Fig. 17.—Tumor removed from the orbit in case 7.

Dr. Lanford reported that the specimen was a conical-shaped mass of tissue the base of which measured about 6 cm. in diameter and the mass about 9 cm. in height. The base presented a wide open palpebral fissure of both lids and a small amount of loose skin over the superior lid. The lid margins presented a few black cilia. The upper half of the palpebral opening was occupied by a spherical mass about 2.5 cm. in diameter the surface of which was covered by a pale gray wrinkled coat. Lying below and protruding farther than the upper mass was another spherical body nearly twice the diameter of the superior one and covered by a moist, pale yellow membrane, probably the stretched lining fold of the conjunctiva sac. The sides of the mass presented a slightly regular appearance, being in general pink and covered with small shreds of bright red tissue. Toward the apex, stumps of the blood vessels and nerves were encountered. In consistency the mass was generally firm though somewhat loose. The diagnosis was glioma of the optic nerve, nonmetastasizing (figs. 18 and 19).

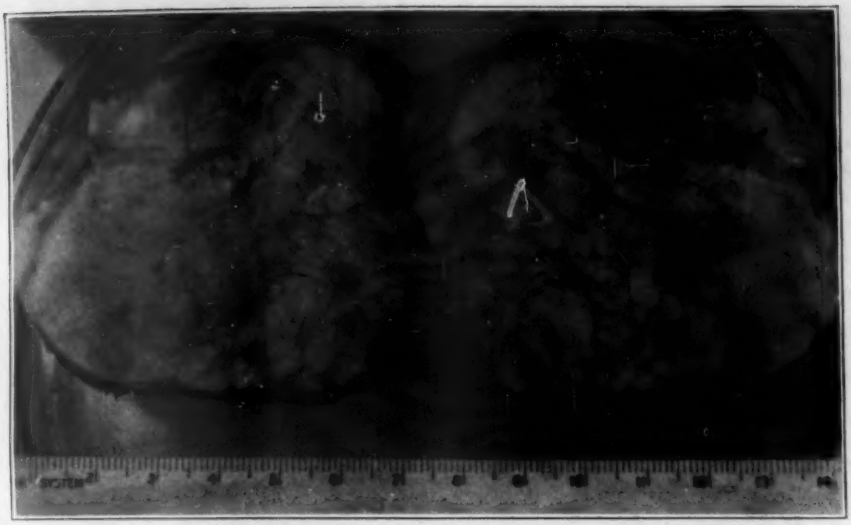

Fig. 18 (case 7).—Appearance of melanoma of the orbit after sectioning.

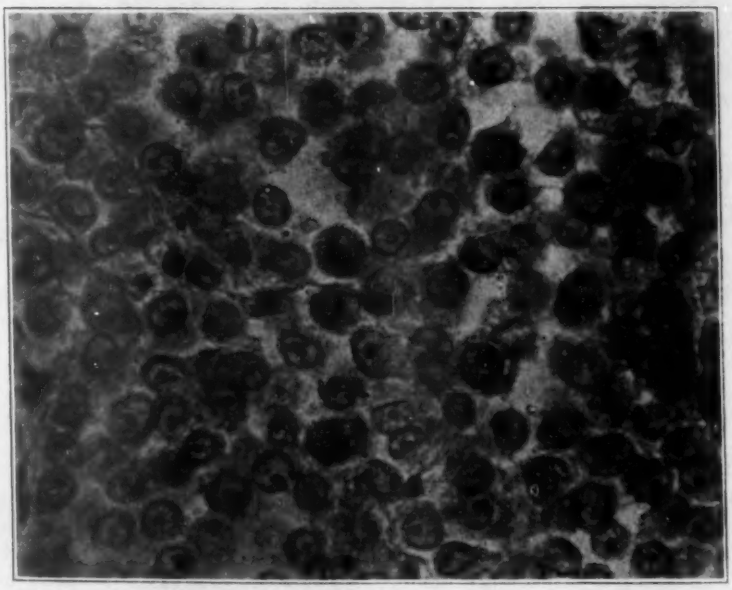

Fig. 19 (case 7).—Microscopic view of section of tumor removed from the eye.

The patient left the hospital on June 18, 1928. He was kept under observation in his home town. He died during June, 1929.

During the last few months of his illness the patient developed a number of growths on the thoracic wall and on the back (fig. 20). I was fortunate enough to obtain one of the tumors which had developed on the thoracic wall at a partial post-mortem examination done by the physician in attendance at the time of death. This specimen was submitted to Dr. Lanford, pathologist, who reported as follows:

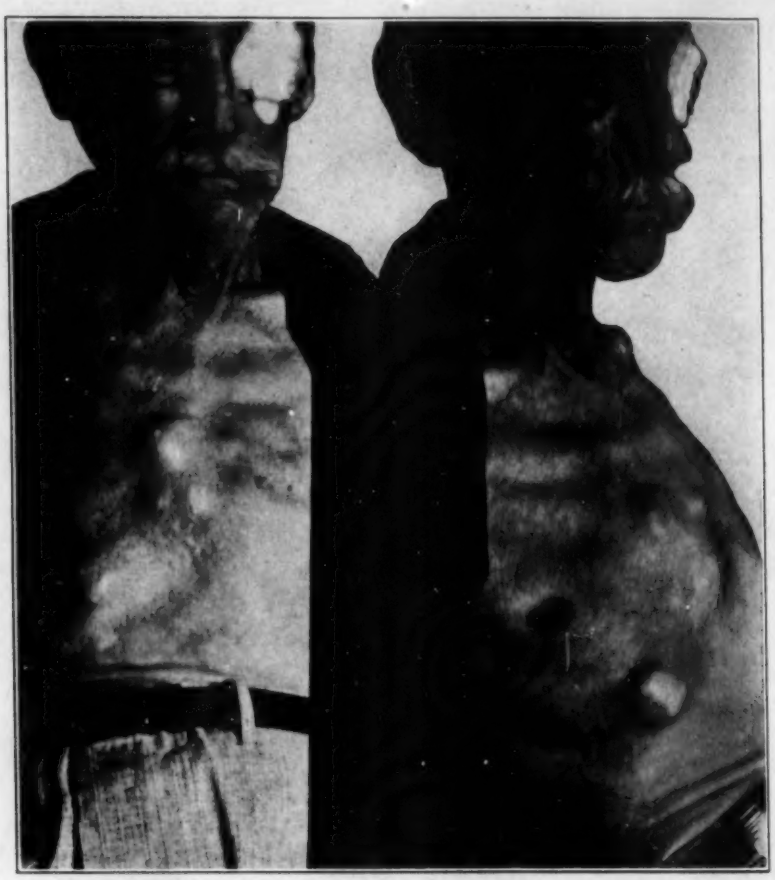

Fig. 20 (case 7).—Appearance of patient a few days before death, showing metastatic growths on the chest wall.

Examination of the nodule from the patient's chest showed it be made up almost entirely of neoplastic cells of rather polygonal shape which in areas were held together by a stroma, the origin of which it was not possible to determine. These cells were not definitely differentiating into the usual type of tissue, such as a carcinoma or sarcoma, and had the histologic suggestions of melanoblasts, but it was impossible to determine the formation of pigment, except that occasionally a few fine brownish granules were found. Dr. Lanford was inclined to look on the new growth as a melanoma (fig. 21).

The interest in this case was great prior to the development of the secondary growths, the association of which with the primary growth Dr. Lanford doubted originally.

When I received the original report of glioma of the optic nerve, I was immediately interested in investigating the frequency of gliomas involving the orbital contents. The more I investigated the literature, the greater were my doubts of the gliomatous nature of the tumor.

In 1912, Curt Adams reviewed the cases of glioma of the retina that had been seen in von Michel's clinic in Berlin during twenty years. He found that there had been one glioma of the retina for every 5,832

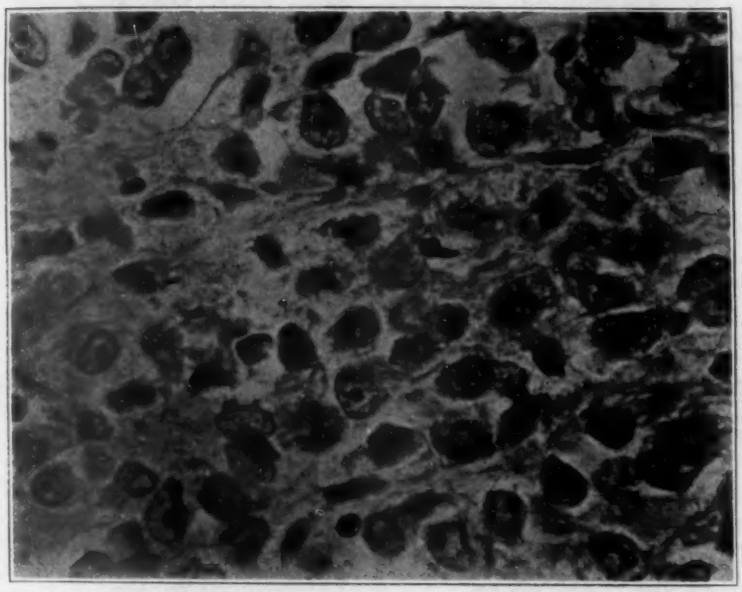

Fig. 21 (case 7).—Section of nodule from the chest indicative of melanoma.

patients. Caspar reported finding only three gliomas in 40,000 patients with involvement of the eye. Paul Berresford of London reported in 1916 the experience of the Royal London Ophthalmic Hospital during the past twenty-four years. He found one glioma of the retina in 96,144 cases.

From these statistics I was impressed with the extreme rarity of glioma of the retina.

Curt Adams' report from von Michel's clinic stated that all the patients were less than 12 years old; 94 per cent were under 4 years. Berresford noted that 41 per cent of the cases occurred during the first year of life. None of the patients was more than 6 years of age. Ewing stated that glioma of the retina appears almost exclusively in

infants; 94 per cent were under 4 years of age. In the "Encyclopedia of Ophthalmology," it is stated that no true case has been found after the sixteenth year. These statements are bound to reflect some doubt on the diagnosis of glioma in our case.

In regard to the characteristics of gliomas of the optic nerve, I found the following statements in the literature which seem to me of value to one attempting to arrive at a differential diagnosis. The question may be asked: Does the tumor described meet the following requirements which were set up by various authorities with reference to glioma of the optic nerve?

In the "Encyclopedia of Ophthalmology" the following statement is made:

> Gliomas of the retina (neuroepitheloma [Flexner]) are never pigmented. The mass is composed of small cells in a soft basement substance. The cells consist of nuclei surrounded by protoplasm in which minute processes are often found. *Some are glia cells, others are ganglion cells. It is a disease of childhood.*

Ewing, in his book on "Neoplastic Diseases," said:

> Characteristic clinical behavior and peculiar structure render glioma retinae one of the most striking examples of a specific tumor process.
>
> The tumors grow expansively. *Metastases are late or absent,* but recurrence is common, and secondary growths appear in brain, skull, spinal cord, regional lymph nodes, and internal organs.
>
> The essentially gliomatous character of these tumors appears in the presence of very many well formed neuroglia fibrils, which with specific stains are nearly always demonstrable and often form a very prominent structural feature.

According to Dr. James Ewing, who examined this tumor, there were no cells that he could consider glial cells.

Glioma recurs, but metastases are late or absent. The patient in question did not have a recurrence but did develop metastases. The secondary growths were classified as melanomas by Lanford.

Because of the existing doubt, Dr. Harold Cummins, a professor in the department of anatomy of Tulane University, was asked to examine the tumor with a view to determining, if possible, the embryologic origin of the growth. He reported that he found heavy pigmented cells within the eye which he took to be evidence of melanoma arising from choroid pigment cells.

Further investigation of the literature then revealed the following important facts with reference to orbital melanomas: Orbital melanomas are found in the conjunctiva, iris, choroid, sheath of the optic nerve and surrounding tissue. These growths are slow in their development. Histologically they may or may not contain pigment. The cells, according to Ewing, may be spindle shaped, round or polyhedral, appearing diffusely or in alveoli.

In view of the presence of pigmented cells in the tumor, which occurred in a man past 70 years of age, and later the development of a number of tumor masses on the surface of the body which histologically presented evidence of pigment-bearing cells, it seemed desirable for Dr. Lanford to review the original growth and to submit this specimen to other pathologists for examination. Dr. Lanford, after studying the

Fig. 22.—Melanoma of the orbit (Ewing) in case 7.

original growth in the light of the metastases, concluded, with Drs. Ewing and Cummins, that the primary growth was a melanoma.

Dr. Lanford reported that he had reviewed the slides from the eye and had studied sections from other areas, and while his first interpretation of the pigment was that it was from the sclera, subsequent events had convinced him that it was the product of a growing tumor cell. He therefore believed that we were dealing with a melanoma probably in addition to a glioma.

A specimen of the original tumor was submitted to Dr. James Ewing, who examined it and reported that it was his opinion that the tumor was a "very cellular actively growing melanoma. It contains very little pigment, but the structure is typical. In the orbit, it is safe to assume that it arose from the choroid." In a subsequent communication he said, "I am quite unable to find any trace of glial tissue" (figs. 22 and 23).

Fig. 23.—Melanoma (Ewing) in case 7.

This simplifies the entire problem, because it permits the acceptance of the secondary growths as metastases. The reporting of two unusual types of growths in the same person, particularly since the secondary growths appeared so soon after the removal of the original growth, would have been difficult to defend.

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TRAUMATIC PNEUMOCEPHALUS

REPORT OF EIGHT CASES *

CARL W. RAND, M.D.
LOS ANGELES

The term traumatic pneumocephalus [1] may be broadly used to designate the entrance of air into the brain or cranial cavity following a fracture of the skull. This air may produce a pocket in the substance of the brain itself, occupy the ventricular chambers, or less frequently disperse itself along the subdural spaces. In the great majority of cases the fracture of the skull involves one of the accessory nasal sinuses, most often the frontal. Cases, however, have been reported in which the line of fracture did not communicate directly with an air-containing sinus. The appearance of pneumocephalus may be immediate or remote. It has been known to develop within a few hours after the accident; on the other hand, instances have been reported in which it appeared from ten to seventeen months following an injury to the head. Whenever this condition is suspected clinically—as should always be the case in the presence of cerebrospinal rhinorrhea—roentgenograms should be made at once. The disclosure of a collection of air within the brain substance or the cerebral ventricles will give an immediate and graphic picture of the contingency to be met.

For many years it had been known that occasionally, following an injury to the head with a fracture of the skull involving a sinus, air might pass through the outer wall of such a sinus under the subaponeurotic layer of the scalp, in which event an aerogenous tumor or tumors might form. Wernher,[2] in 1873, reported such a condition. This extracranial form of pneumocranium more frequently follows a fracture in the mastoid region than one in the frontal sinus. Such accumulations of air under the scalp, however, must be exceedingly rare. I

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* Submitted for publication, Nov. 12, 1929.

1. Many terms have been used to describe this condition, i. e., aerocele, pneumocele, pneumatocele, hydropneumatocele, pneumocranium, hydropneumocranium, ventriculocele, pneumoventricle, etc. Pneumocephalus, however, seems to be the most logical. As Bullock pointed out, there is a certain analogy between hydrocephalus and pneumocephalus (Traumatic Pneumocephalus, Surg. Gynec. Obst. **43**:750 [Dec.] 1926). Hydrocephalus not only describes a condition of "water on the brain," but has been a word familiar to physicians for many centuries. Hydrocephalus may be divided into the internal or external variety, depending on the position of the water. He argued that "a similar disposition is found to exist with air collections, which may with equal propriety be designated as internal or external pneumocephalus." It is recognized that pockets of air may be produced in the brain from infective organisms such as the Bacillus aerogenes-capsulatus of Welch or the colon bacillus; such conditions, however, are largely speculative and will not be considered in this paper.

2. Wernher: Pneumatocele cranii, Deutsche Ztschr. f. Chir. **3**:381, 1873.

have never seen such a case, although several examples of crepitant emphysema of the soft tissues about the face and eyes following fractures of the frontal sinuses have come to my notice. These extracranial forms of aerogenous tumors were usually treated by a simple pressure bandage, and healed spontaneously as granulation tissue filled in the defect in the bone. They are mentioned only as being analogous to the more common and more dangerous intracranial variety.

The roentgenogram has been chiefly responsible for the increased recognition of intracranial pneumocephalus. Before the advent of the roentgenogram, it was practically never diagnosed. In 1884, however, Chiari [3] recognized one of the first cases in a patient with a previous history of chronic inflammation of the ethmoid cells. The walls of these cells had been weakened and the dura eroded, so that following violent sneezing air was forced from a small rent in the dura connecting with the ethmoid cells into the frontal lobe and ventricles of the brain. At autopsy, he demonstrated the air pocket in the frontal lobe as well as the air in the ventricles, and argued that this collection of air had been present during life, explaining its entrance as a result of the explosive force of sneezing. Violent sneezing had been one of the outstanding symptoms which immediately preceded the onset of severe headaches, stupor and death.

The first case of traumatic pneumocephalus to be demonstrated by roentgenograms was one by Luckett,[4] in 1913. His patient had received a fracture of the skull involving the right frontal sinus. Roentgenograms taken at the time of injury revealed the fracture, but no air was apparent in the ventricles. The patient did well for some time, but on the nineteenth day he sneezed and apparently inflated the ventricles. He remarked to a friend, "I just sneezed, had a terrific pain in my head, and then a flow of a large amount of clear fluid came through my nose, about a cupful." Signs of increased intracranial pressure immediately followed, and subsequent roentgenograms of the skull showed the entire ventricular system, as well as a pocket in the right frontal lobe, to be distended with air. Recognizing the seriousness of this condition, Luckett at once performed a right subtemporal and a suboccipital decompression, removing the air both from the ventricles and from the cisterna magna. Meningitis, however, was already present and the patient died four days later, the air infiltrated ventricles being disclosed at autopsy.

Dandy,[5] in 1926, reported three new cases of traumatic pneumocephalus, collected twenty-five others from the literature, and gave an

3. Chiari, H.: Ueber einen Fall von Luftansammlung in den Ventrikeln des menschlichen Gehirns, Prag. Vierteljahrsschr. f. Heilk. **5**:383, 1884.

4. Luckett, W. H.: Air in the Ventricles of the Brain Following a Fracture of the Skull: Report of a Case, Surg. Gynec. Obst. **17**:237, 1913.

5. Dandy, W. E.: Pneumocephalus: (Intracranial Pneumatocele or Aerocele), Arch. Surg. **12**:949 (May) 1926.

admirable review of the subject. He suggested a practical method of treating this condition, by releasing the entrapped air, searching out the dural defect and closing the same either by a direct suture or a fascia lata transplant. His method of approach varied, depending on the type of fracture and the position of the dural rent. Two procedures were suggested: (1) simple exposure of the fracture near the supraorbital ridge and correction of the dural defect which lay directly beneath, or (2) the use of an extensive frontal bone flap, with search for the dural defect along the posterior wall of the frontal sinus or in the region of the ethmoid cells, and closure of the same. Five years earlier, Spiller [6] had discussed the treatment as follows:

> The question of operation is a difficult one. If it is to be performed early, it will be before any evidence of aerocele exists, and will be done in the hope of preventing this lesion. It is not customary to operate on every case of linear fracture of the skull without displacement of fractured bone and without signs of intracranial pressure, and it seems questionable whether operations would be advisable whenever the roentgen rays show a linear fracture permitting communication with air sinuses. In some instances it is difficult or impossible to be certain from roentgen-ray examination whether an air communication with the interior of the cranium has been established. Presumably where such communication is shown by roentgen-ray plates taken shortly after fracture has occurred, operation might make closure of this communication possible and thus prevent the development of an aerocele, and the possibility of the development of an aerocele must be considered in any case of fracture of the bones about the nose. It would be difficult to prevent the patient from blowing the nose and sneezing in the presence of such fracture, but something might be attempted in this direction to lessen the danger.

Bromberg,[7] in 1928, reported a case of typical frontal pneumocephalus with cerebrospinal rhinorrhea, appearing seven weeks after a frontal fracture. He attempted to close the rent in the dura by the use of the roentgen ray, but was unsuccessful. Following a suggestion of Israel Strauss, the patient was placed in bed with his head held backward so that the nasal cavity would lie in a horizontal position. He was kept in this position for three weeks or more without turning his head, every precaution being taken to prevent coughing, sneezing or straining. At the end of the month the air had practically disappeared from his brain, and after two or three months he was entirely well.

In the traumatic form of pneumocephalus one has an initial cranial defect connecting with one or more of the paranasal sinuses or with the mastoid cells. It is well recognized that gaseous pressure may be increased in the paranasal sinuses by coughing, sneezing, straining, swallowing or the like, so that it is much greater than that ordinarily

6. Spiller, W. G.: Aerocele of the Brain, M. Clin. N. Amer. **5**:651 (Nov.) 1921.

7. Bromberg, W.: Cerebrospinal Rhinorrhea with Pneumocephalus Secondary to Skull Fracture, J. A. M. A. **90**:2017 (June) 1928.

existing within the cranial chamber. Consequently, when there is a fracture connecting with such a sinus and the intracranial cavity by a dural rent, air may be forced from any of these sinuses into the brain substance itself. Connections with the frontal sinuses are most common, but cases have been reported in which the communication has been with the ethmoids (Chiari,[3] Holmes,[8] Doyle[9] and Spiller[6]), the sphenoids (May[10] and Santoro[11]) or the mastoids (Duken,[12] Teachenor[13] and Dandy[14]). The entrance of air into the brain and ventricles may be immediate, as was true in two cases of this series, but it more frequently happens from two to four weeks after the injury. Conversely, a pocket of air may exist in the substance of the frontal lobe for many months without breaking through into the ventricle.

Several factors favor the frontal region as the most common site for the development of pneumocephalus. Fractures frequently occur in the frontal sinuses, and the dura in this region is thin and very tightly adherent to the skull. A fracture of the inner wall of the sinus is only too prone to cause a rent in the dura as well. There is usually a contusion or laceration of the frontal lobe in the immediate proximity of the fracture, consequently adhesions tend to form, walling off the bruised brain at the point of fracture from the surrounding subdural space. Ideal conditions are therefore produced for the passage of air directly from the sinus into the brain substance, if by chance the pressure within the sinus itself is suddenly increased. Hence coughing, sneezing, straining or anything that will raise the gaseous pressure within the sinus is most often the immediate predecessor of the entrance of air into the brain or ventricles.

Dandy called attention to an unusual condition of the sinus which not infrequently exists. The size or character of the sinus may be such as to permit the outflow of spinal fluid as seen in cerebrospinal rhinor-

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8. Holmes, G. W.: Intracranial Aerocele Following Fracture of the Frontal Bone, Am. J. Roentgenol. **5**:384 (Aug.) 1918.

9. Doyle, A. S.: Traumatic Pneumocranium, Am. J. Roentgenol. **8**:73 (Feb.) 1921.

10. May, R. J.: Report of a Case Showing Air Within the Cranial Cavity, Am. J. Roentgenol. **6**:190 (April) 1919.

11. Santoro: Rinorrea cefalo-rachidiana e pneumoventricolo spontanei da tumore della base (ipofisi?), (Spontane Liquorrhinorrhoe und Pneumoventrikel bei einer Basis- (Hypophysen-?) (Geschwulst), Riv. oto-neuro-oftalmol. **1**:484, 1924.

12. Duken: Ueber zwei Fälle von intracranieller Pneumatocele nach Schussverletzung, München med. Wchnschr. **62**:598, 1915.

13. Teachenor, F. R.: Pneumoventricle of the Cerebrum, Ann. Surg. **78**:561 (Nov.) 1923.

14. Dandy, W. E.: The Treatment of Staphylococcus and Streptococcus Meningitis by Continuous Drainage of the Cisterna Magna, Surg. Gynec. Obst. **39**:760 (Dec.) 1924.

rhea, but not adapted to allow the escape of the entrapped air. It has been argued that a ball valve action may exist along the sinus tract, which will permit entrance of air into the cranial chamber but which prevents its exit. Cases have been reported in which the entrance of air was apparently simultaneous with the stoppage of cerebrospinal rhinorrhea. This, however, does not necessarily follow, as cases have been known in which signs of meningitis appeared as soon as the cerebrospinal rhinorrhea stopped, no air being present within the cranial chamber. The reverse, however, is more frequently seen.

The symptoms may be sudden or gradual, violent or mild, depending largely on the amount of air and the rapidity of its entrance into the cranial chamber. Usually, the appearance of pneumocephalus is shown by the occurrence of headache, nausea and vomiting; in short, the signs of increased intracranial pressure appear. The patient may show evidences of drowsiness and stupor and even go into coma. Mental changes in the form of disorientation, forgetfulness or even delusions may occur. A choked disk may, or may not, develop. Convulsions have occurred and may be of the jacksonian type. Not infrequently there will be chills and fever, with the characteristic signs of a rapidly developing meningitis. Stiffness of the neck and a positive Kernig sign are the rule. Even in cases in which actual meningitis is not present, symptoms of mild meningeal irritation are seen. These gradually pass away as the patient recovers.

The presence of cerebrospinal rhinorrhea, especially following an attack of sneezing or coughing, is regarded by Dandy [5] as almost pathognomonic of pneumocephalus. He stated: "A cerebrospinal fistula is probably the sign of greatest significance. Its presence should always make one suspect pneumocephalus. . . . When sneezing follows a frontal fracture with rhinorrhea, the suspicion grows stronger, but when sneezing is followed by a flow of cerebrospinal fluid . . . one could almost be safe in making a positive diagnosis of pneumocephalus without the roentgen ray."

REPORT OF CASES

CASE 1.—*Depressed right frontal fracture followed by immediate traumatic pneumocephalus. Elevation of depressed fracture on same day. No attempt made to remove air. Gradual absorption of same, and recovery of patient.*

A. A., aged 23, a Mexican laborer, was injured on Dec. 5, 1919, when he was struck in the right frontoparietal region by a falling piece of a 2 by 4 timber, and was immediately rendered unconscious. He was first taken to the Ramona Hospital in San Bernardino, then transferred to the Good Samaritan Hospital in Los Angeles. At the time of his entrance to the latter hospital, he was found to be suffering from an extensive compound, comminuted, depressed fracture of the right frontal region. Brain substance was oozing from the laceration in the scalp into his hair. He was in deep coma and having frequent convulsions. He was taken to the operating room, where Dr. Shoemaker elevated the depressed fragments. At the time it was noticed that bubbles of air came through the

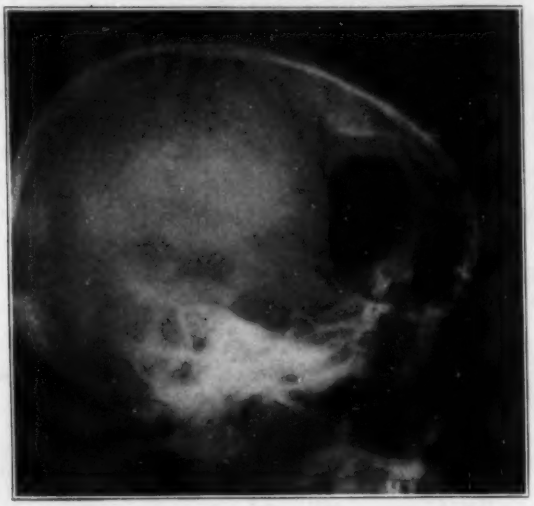

Fig. 1 (case 1).—Postoperative roentgenogram taken several hours after injury, showing a large pneumocephalus of the right frontal lobe. Apparently the dural defect was inadvertently closed at operation as the pneumocephalus absorbed and did not recur.

Fig. 2 (case 1).—Roentgenogram taken a few hours after operation, showing corrected fracture of the right frontal bone as well as air in the right frontal lobe and partial filling of the ventricle; this air was absorbed spontaneously.

tissues above his right eye. Roentgenograms of the skull taken immediately after operation showed a large pocket of air in the right frontal lobe and also partial filling of the ventricles (figs. 1 and 2). The patient recovered without any attempt being made to remove this air, and further x-ray plates taken on March 30, 1920, showed it to have been absorbed from the ventricles and largely absorbed from the pocket in the right frontal lobe. The last roentgenograms, taken on July 14, 1920, showed complete disappearance of the air (fig. 3). It is felt that the dural rent was inadvertently closed at the time of operation, preventing the further entrance of air into the cranial cavity. (This case is reported through the curtesy of Dr. Harlan Shoemaker of Los Angeles.)

CASE 2.—*Right frontal fracture with removal of the depressed fragments on the same day. Immediate appearance of cerebrospinal rhinorrhea which stopped four weeks later when pneumocephalus and meningitis appeared. Death from meningitis.*

Fig. 3 (case 1).—Roentgenogram taken approximately four months after injury, showing the frontal fracture still present, but all air within the cranial cavity has been absorbed.

R. L. W., aged 24, married, a fireman, was referred by Dr. William T. Cade, Jr., of Los Angeles, on May 3, 1926. He was injured on April 4, 1926, when he was struck on the forehead with the nozzle of a fire hose. He sustained a compound, comminuted, depressed fracture of the skull in the right frontal region, but was not unconscious. At the Pacific Hospital he was operated on by Dr. C. F. Nelson three hours after the injury, large fragments of depressed bone being removed. A cerebrospinal rhinorrhea developed immediately following the injury, and spinal fluid continued to drip from his nose until April 30, when it suddenly stopped. The patient had made a good primary recovery from his operation and had been discharged from the hospital at the end of two weeks.

A pneumocephalus became apparent about four weeks after the injury. The patient had been home approximately two weeks, with the cerebrospinal rhinorrhea still present. On April 30, the fluid stopped running from his nose; he felt sick and chilly, and during the night his temperature rose to 104 F. The next morning, he was unconscious and remained in coma until his death on May 5. Two days before death, there was twitching of the right side of the face.

At the time of my examination on May 3, the man was exceedingly ill and in deep coma; the temperature was 104 F.; pulse rate, 200 and respirations, 40. He was bathed in perspiration; there was marked rigidity of his neck, a double positive Kernig sign, marked swelling and edema of both eyelids, and the tissues about the forehead were boggy. Brain substance oozed from a recent stab wound just above the bridge of the nose. The pupils were unequal and fixed, the right being larger than the left; the eyegrounds showed marked congestion of both fundi and haziness of the disk margins. All superficial and deep reflexes were in abeyance. The white blood cell count was 43,000; the polymorphonuclears, 85 per cent.

Fig. 4 (case 2).—Roentgenogram taken approximately one month after injury, showing defect in the frontal bone from removal of depressed fragments and a pocket of air in the right frontal lobe.

Roentgenograms of the skull taken at this time revealed a comminuted fracture of the right frontal bone, with a large defect where fragments had been removed, and a large pneumocephalus in the right frontal region (figs. 4 and 5). A spinal fluid examination at this time showed the fluid under great pressure, containing many gram-positive organisms, probably pneumococci. The patient died on May 5, and the coroner reported that death had been caused by depressed fracture of the skull and acute meningitis.

CASE 3.—*Depressed right frontal fracture followed by fever and slow convalescence. Five weeks later, signs of meningitis and traumatic pneumocephalus.*

Operative attempt to correct dural rent and relieve pneumocephalus. Meningitis already present. Death from streptococcus meningitis.

J. J., aged 13, a newsboy, was referred by Dr. C. L. Gaulden of Los Angeles on April 22, 1927. On March 5, the boy was struck by an automobile, receiving a compound, slightly depressed fracture in the right frontal region. He was rendered unconscious and remained so for about two days. From the onset, he had bleeding from the right ear and later a purulent discharge from this ear; he also had a right peripheral facial paralysis from the first.

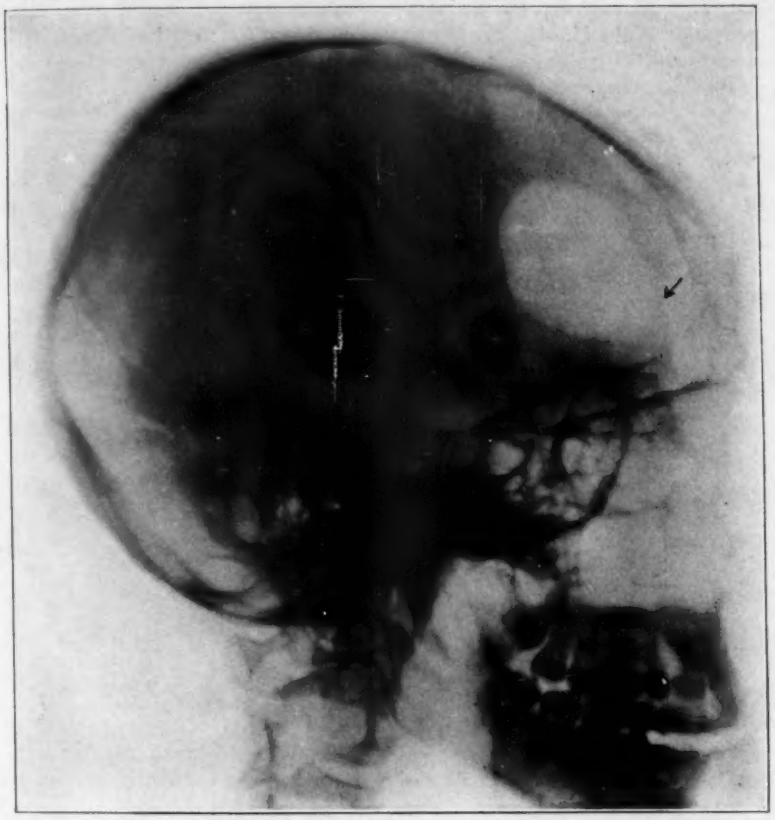

Fig. 5 (case 2).—Roentgenogram taken one month after injury, showing a large pocket of air in the right frontal lobe. Point of communication of the air pocket with the region of the frontal sinus indicated by arrow.

Roentgenograms of the skull taken on March 9, revealed a rather extensive Y-shaped fracture in the right frontal region. At the fork of the Y one could see a triangular piece of bone which was slightly depressed, but no air was present. The patient had an intermittent fever from the first, and there was a serous discharge from his right ear which may have been spinal fluid. About the middle of April, 1927, he began to get worse.

On April 22, he was found lying on his left side; he refused to turn on his back because of pain in his head and neck. The neck was quite stiff, and there

was a double positive Kernig sign. There was a healed scar in the right frontotemporal region. The pupils were unequal, the right being considerably larger than the left; both reacted well to light and distance. There was a complete peripheral facial paralysis on the right. The discharge from the right ear had ceased. The eyegrounds were within normal limits, save for some congestion of the retinae and vessels. The deep reflexes were all present and equal, except the left knee jerk, which was quicker than the right. There was a positive Babinski sign on the left; a negative on the right. An examination of the spinal fluid showed a slightly cloudy fluid under pressure which contained 152 cells per cubic millimeter and reacted positively to the Noguchi test and negatively to culture. Examination of the blood showed hemoglobin, 75 per cent; erythrocytes, 4,440,000; leukocytes, 10,350; color index, 0.9; polymorphonuclears, 80 per cent; large mononuclears, 18.5 per cent; transitional leukocytes, 1.5 per cent.

Fig. 6 (case 3).—Roentgenogram taken approximately six weeks after injury, showing air in the right frontal lobe and practically filling the ventricular system; postero-anterior view.

Roentgenograms of the skull taken on April 22 revealed an old fracture in the right frontal region. The entire ventricular system was filled with air (fig. 6). In the right frontal lobe just in front of the anterior horn of the ventricle one could see a pocket of air. It was evident that the patient had developed a traumatic pneumocephalus, the air coming through the right frontal sinuses. It seemed advisable to try to empty the air from the pocket and ventricles, and if possible close the opening in the dura.

At operation, the fracture line in the right frontal bone was exposed. On rongeuring the bone, bubbles of air escaped between the dura and the inner table of the skull. The dura was at least four times its normal thickness. The surface of the frontal lobe showed inflammation with exudate and thickening of the pia.

The lateral ventricle was entered by needle, when bubbles of air and a very cloudy fluid came out. This fluid later showed 4,320 cells per cubic millimeter, and a pure growth of nonhemolytic streptococcus was obtained. A drain was placed in the wound. The opening in the dura through which the infection had entered was not found. The wound continued to discharge a profuse amount of turbid fluid for the next two days, and the boy died on April 24.

CASE 4.—*Linear fracture left frontal bone involving left frontal sinus; no complications for four weeks; then appearance of headaches and drowsiness with discovery of traumatic pneumocephalus. Release of air; correction of dural defect; recovery.*

Fig. 7 (case 4).—Roentgenogram taken approximately four weeks after injury, showing a large pocket of air in the left frontal lobe and partial filling of the lateral ventricle.

C. W., aged 19, single, a laborer, was referred by Dr. Wallace Dodge of Los Angeles on April 21, 1928. He was injured on March 29, 1928, when he was struck in the midforehead, just below the hair line, by a falling piece of timber. He was unconscious for a very short time. A roentgenogram taken at the Methodist Hospital on the date of his injury showed a linear fracture in the left frontal bone, which ran into and involved both walls of the left frontal sinus. The patient presented no unusual neurologic signs or symptoms during the next two weeks, and at the end of this time was allowed up in a wheel chair. On April 15, he began to have a headache and to vomit. The headache and vomiting continued daily for the next week.

At the time of my first examination on April 21, he was mentally clear and conscious. The scar in his forehead was healed and clean. The neck was a little resistant, and a Kernig sign was suggestive on both sides. The eyegrounds were normal, and the pupils were equal and reacted well to light and distance. Otherwise, the results of the neurologic examination were negative. It was felt at the time that there was a suggestion of increased intracranial pressure, possibly an extension of infection from the frontal sinus; a traumatic pneumocephalus was not considered, but a brain abscess was thought likely. On April 26, roentgenograms of the skull were again made, and a large pocket of air was disclosed within the substance of the left frontal lobe (fig. 7). The lateral ventricles

Fig. 8 (case 4).—Roentgenogram taken about five weeks after injury showing a pocket of air in the left frontal lobe communicating with the region of the left frontal sinus; the lateral ventricles are also filled.

were also filled with air (fig. 8). One could see a direct communication of air from the posterior wall of the left frontal sinus into the pneumocephalus. It was felt advisable to keep the boy absolutely quiet in bed, warning him against coughing or sneezing, and not permitting him so much as to raise his head. No cerebrospinal rhinorrhea was present. This treatment was carried out for two or three days with fair relief from headache and vomiting, when the symptoms again recurred, and an exploration was advised.

On May 2, a left frontal osteoplastic flap was turned down according to the method of Dandy. The dura was found to be very tense, and the flattened convolutions of the frontal lobe could be seen shining through. The dura was nicked, and a ventricle needle was introduced into the air pocket beneath. This

was encountered at a depth of 2 cm., and air came out with a whistle through the needle. Following this the frontal lobe collapsed and all tension was removed from the dura, permitting it to be reflected back from the inner surface of the skull. The fracture in the frontal bone was investigated in both the anterior and posterior walls of the left frontal sinus, and found to be more extensive in the latter. The mucous membrane was torn, and air rushed in and out when the patient breathed. Just overlying this rent in the mucous membrane was a defect in the dura, measuring about 1 by 0.5 cm. and located at the posterior margin of the left frontal sinus near the cribriform plate. The rent in the dura was partially closed by suturing, but could not be entirely repaired, and consequently

Fig. 9 (case 4).—Photograph of patient taken several months after injury showing faint operative scar in the left frontal region.

was sealed with a piece of fascia lata taken from the right thigh. The fascial graft was reinforced by several pieces of muscle. The wound was then closed tight.

The patient had persistent vomiting for several hours following the operation. His temperature remained around 102 F. for two days, then dropped to normal, and convalescence was uneventful (fig. 9). He returned to light work about July 15, 1928, three and one-half months after his injury.

CASE 5.—*Extensive depressed fracture involving both frontal sinuses. Refusal of operation for correction of same. Appearance of signs of meningitis and pneumocephalus one month later. Correction of depressed fracture; closure of dural rent and relief of pneumocephalus at this time. Recovery.*

F. G., aged 23, married, an actress, entered the Los Angeles General Hospital on May 17, 1928. The details of her accident were not very clear; however, it

was learned that she fell downstairs, striking her head on some hard object. When admitted to the hospital she was in a semicomatose condition; there was ecchymosis about both eyes, which were swollen shut, and the forehead was puffy with a laceration near the midline. Palpation revealed a depression of the bone in the midfrontal region. The pupils were equal and reacted well to light and distance; the eyegrounds were within normal limits. There was no bleeding from the ears, but profuse bleeding from the nose. The results of the neurologic and physical examinations were essentially negative.

A roentgenogram of the skull taken on May 17 revealed a much comminuted fracture in the frontal region involving the anterior fossae on both sides. Several

Fig. 10 (case 5).—Roentgenogram taken approximately a month after injury showing a large pneumocephalus in the right frontal lobe. The fracture lines can be faintly made out. Roentgenograms taken immediately after injury failed to show the presence of air in the cranial cavity.

comminuted fragments appeared to project into the cranial vault in the anterior fossa near the superior external angle of the right side. No air was present in the cranial chamber.

After a few days, the patient's condition cleared up satisfactorily except for rather severe headache. She did not have a cerebrospinal rhinorrhea at any time. She refused to have the depressed fracture elevated, and left the hospital of her own accord on May 29.

She returned on June 15, 1928, very ill. At this time she had a fever of 102.6 F.; pulse rate 120, respirations 20, a stiff neck and a double positive Kernig sign. She was delirious part of the time, restless and resisted examination, had

a terrible headache, and moaned constantly with pain. The eyegrounds showed marked overfilling of the vessels, congestion of the retinae and haziness of the disk margins. The deep reflexes were all much increased and about equal. There was a suggestive Babinski sign on both the right and left side.

A lumbar puncture performed on June 16 showed a turbid fluid under markedly increased pressure; 10 cc. of fluid was removed. The globulin was greatly increased, and the test for sugar was negative. The cell count showed 4,320 cells per cubic millimeter, 95 per cent of which were polymorphonuclears and 5 per cent lymphocytes. A smear showed a few gram-positive, extracellular diplococci resembling pneumococci. It is possible that this was a contamination.

Fig. 11 (case 5).—Roentgenogram taken approximately one month after injury showing a large collection of air in the right frontal lobe. Extensive fracture lines in the frontal region can be well seen.

Pneumocephalus was suspected, and roentgenograms were again taken on June 18. These revealed a large collection of air in the right frontal lobe; the comminuted fracture of the skull in the frontal region extending into the anterior portion of the anterior fossae on both sides was again seen (figs. 10 and 11). There was overlapping at the median transverse side of the fracture, giving an appearance of some depression of the upper fragment and some outward displacement of the lower fragment.

She was operated on, June 20, when a flap of liberal size was turned down in the right frontal region. The dura was under great tension. This was opened, and a pneumocephalus in the right frontal lobe was emptied of air by a ventricle needle, the air coming out under great pressure. The dura was then lifted from

the floor of the anterior fossa, and two rents were discovered. Through one of these, a pointed spicule of bone had penetrated from the frontal sinus. This rent was sutured. A second rent was found deep down over the cribriform plate at a point where suture of the dura was impossible. Consequently, a piece of muscle and fascia lata were removed from the left thigh, and the defect in the dura was closed with them. The depression in the frontal bone was corrected, and the wound closed tight. Convalescence was stormy. By June 26, all air had disappeared from the cranial cavity, as was revealed by subsequent roentgenograms. The patient continued to have headaches and signs of meningeal irritation, and lumbar punctures were made from time to time. She was given methenamine intravenously, as much as 90 grains (5.8 Gm.) a day being given for short periods of time. From the time of her second admission, until her discharge, she was given 1,920 grains (124.4 Gm.) intravenously. The kidneys were watched closely and apparently suffered no ill effects. It could not be definitely proved whether formaldehdye was transmitted in the spinal fluid. Lumbar punctures were repeated from time to time and the results were as follows: On June 23, 10 cc. of fluid was removed; it was cloudy and contained 1,650 cells per cubic millimeter. The globulin was increased. A few extracellular gram-positive diplococci were seen. These may have been due to a contamination. On July 4, 65 cc. of fluid was removed; it was turbid, and under increased pressure and contained 1,650 cells per cubic millimeter. Smears or cultures were not made. On July 10, 75 cc. of fluid was removed; it was turbid and under increased pressure and contained 1,520 cells per cubic millimeter. On July 20, 100 cc. was removed; it was clear but yellowish and contained 1,285 cells per cubic millimeter, which were mostly lymphocytes. It was noted that the patient seemed better when spinal punctures were not made, consequently, no further punctures were carried out.

During the first weeks after the operation, the patient was noisy, delirious and very difficult to handle; in fact, she had to be put in the psychopathic ward for a time. Gradually her condition cleared up, and by August 14, she had apparently completely regained her mental faculties, the wound was well healed and she was discharged from the hospital. Correspondence with her from time to time since reveals that she remains in good health.

CASE 6.—*Occipital and questionable right frontal fracture, with immediate cerebrospinal rhinorrhea and pneumocephalus. Six days later sudden stoppage of rhinorrhea and appearance of signs of acute meningitis; disappearance of air at this time. Death from pneumococcus meningitis.*

C. S., aged 41, married, a carpenter, was referred by Dr. A. W. Moore of Los Angeles. He was injured at 10:30 a. m. on May 21, 1928. In attempting to loosen some bolts from the top of a door, he in some way received an electric shock and fell 20 feet. He was not rendered unconscious, but sustained a Colles fracture of the left wrist, minor burns on fingers of the left hand and a fracture of the skull in the right frontal region. There was profuse bleeding from the nose and mouth and a marked cerebrospinal rhinorrhea which began at the time of the accident and stopped suddenly on May 27, six days later. As long as the rhinorrhea continued, the patient's mind was clear and he was conscious, but he had considerable headache. The leakage of fluid stopped about 2 p. m.; his headache became excruciating, and he dropped into coma two hours later, his temperature rapidly rising to 104 F.

Roentgenograms of the skull taken on May 21 (the date of injury) showed an unusual condition. There was practically complete filling of the left ventricle of the brain with air, which also was present in the subarachnoid space over the entire brain (figs. 12 and 13). No air was seen in the substance of either frontal lobe. There was a linear fracture in the right occipital region below the lambdoid

suture and a second line near the outer angle of the eye on the right side which resembled a fracture. Roentgenograms taken on May 28 showed that practically all the air had been absorbed. This, however, did not influence the course of his meningitis.

The patient was first seen by me on May 28, 1928, two days before his death, at which time the right eye was discolored and swollen and the neck stiff, and he had a positive Kernig sign on each side. Divergent squint was present. The right pupil was static and a little larger than the left; the left reacted sluggishly. He was apparently blind in the right eye. The eyegrounds showed marked congestion of the disks, with beginning choking on each side. Respirations were of the Cheyne-Stokes type; the temperature was 104 F.; pulse rate, 80; white blood

Fig. 12 (case 6).—Roentgenogram taken on day of injury showing extensive filling, both of the ventricles and subarachnoid spaces with air. This is the only case in which the subarachnoid spaces filled with air.

cells, 9,500, and polymorphonuclear cells, 68 per cent. A lumbar puncture performed on May 28 showed a spinal fluid under a pressure above 300 mm., and a cell count of 14,000 per cubic millimeter. Gram stain of sediment showed numerous pus cells and a moderate number of gram-positive lanceolate diplococci, some intracellular. Culture showed a pure growth of pneumococcus, group IV. Death occurred on May 30, 1928.

This case differs from the others reported, with the exception of case 1, in that pneumocephalus developed immediately on the day of injury, as shown by the early roentgenograms. As long as the cerebrospinal fluid leak continued, the patient was fairly comfortable; as soon as this stopped, he lapsed into coma and died shortly afterward. Before death, the air had disappeared from the ventricles

and subarachnoid spaces. The definite source of entrance of the air and microorganisms in this case was not determined.

CASE 7.—*Extensive comminuted bilateral frontal fracture communicating with the right frontal sinus. Cerebrospinal rhinorrhea developing about a week later. Appearance of headache, mental hallucinations and discovery of traumatic pneumocephalus about six weeks after injury. Operative closure of dural defect by muscle graft. Recovery.*

J. H. I., aged 44, married, a business man, was seen in consultation with Dr. H. D. Newkirk of Santa Ana on June 11, 1929. On May 6, he sustained an

Fig. 13 (case 6).—Roentgenogram taken on day of injury showing air in the lateral ventricles and a large collection in the subarachnoid spaces.

extensive fracture of the skull in the frontal region. The circumstances surrounding his injury were not clear. He was found in a basement, unconscious, with lacerations of the scalp, especially in the left frontal region, and a fracture of his left elbow. There was no bleeding from his ears. After a day or two his condition began to clear up, and improvement continued until June 9.

Roentgenograms of the skull taken soon after the accident showed an extensive fracture in the frontal region. There was a very small depression in the left temple just outside of the orbit; this depression measured approximately 1 by 1.5 cm., and was pushed down about 0.5 cm. There were other fracture lines run-

ning across the frontal bone, one communicating with the right frontal sinus. No air was seen inside of the cranial cavity.

On June 9, he exhibited his first delusions. He insisted that his wife was with him and that she was taking care of him. As a matter of fact, she was 500 miles away. He also became confused and disoriented. He did not know where he was, or that he was in a hospital. He lost all interest in his business, never inquired about it and showed no worry regarding it. This was quite different from his normal mental attitude.

On examination on June 11, the patient appeared to be in good general physical condition. There were two recently healed scars on the left side of the forehead.

Fig. 14 (case 7).—Roentgenogram taken approximately seven weeks after injury. A tremendous pneumatocele is evident in the right frontal lobe as well as the presence of air in the lateral ventricle. The fracture lines can be made out in the frontal bone.

In the left temple, just outside of the orbit, one could feel a very slight depression in the bone. The cranial nerves were normal, and the eyegrounds appeared to be within normal limits. There were no abnormal reflexes of the Babinski group nor ankle clonus on either side. He used all extremities well.

Laboratory examinations showed the urine and Wassermann reaction of the blood to be negative. The blood count showed: hemoglobin, 84 per cent; red blood cells, 4,610,000; color index, 0.93; white blood cells, 10,200; polymorphonuclears, 70 per cent; lymphocytes, 27 per cent; mononuclears, 3 per cent; blood grouping, II.

The patient seemed quite well oriented on the day of this examination. He knew that he was in a hospital at Anaheim, gave the day of the week and month correctly and discussed his business in some detail. He performed the 100-7 test very quickly and accurately and seemed mentally himself, except for one delusion. He insisted that his wife was in the hospital with the two children, and he could not be persuaded otherwise. As already stated, she was at their home 500 miles away.

About this time a cerebrospinal rhinorrhea was observed; the exact time of its development is not known. After his recovery the patient said that it started within a week from the date of his injury, but it was not conspicuous until a

Fig. 15 (case 7).—Roentgenogram showing multiple fracture lines and a large collection of air both in the right frontal lobe and filling the ventricular system.

month later. The fluid came from the right side of his nose and in large quantities. He also developed considerable headache. At times his headache was very severe; at other times he was apparently free from pain. When the headache was present, he was usually badly confused as to time and place. When the headache was absent, his mind, for the most part, was clear. Abstracts from a letter written on June 16, 1929, will perhaps give an idea of his mental condition.

"Anaheim Aeriatarium
Anaheim, Oct. 17, 1929 (Correct date June 16, 1929).

Your letter enclosing the dried peaches and dried fruit bag arrived this morning early. Every thing in it were fine. The fruit was fine also.

Our paper and stamps are getting low so we take advantage of writing on the other fellows paper etc.

I did not do that today because I did not hear that the box contained so much stuff so direct from San Meioijoioinhajones's."

He was brought to Los Angeles on June 26, when he was found to be in a very confused condition. Roentgenograms of the skull were taken again at this time as a traumatic pneumocephalus was suspected. These plates showed a tremendous collection of air in the right frontal lobe and filling the lateral ventricles (figs. 14 and 15). The patient was operated on two days later, a right frontal bone flap being turned down. On reflecting the flap, to our surprise the dura had collapsed and it was apparent that the pneumatocele had emptied itself. On reflecting the dura from the back of the right frontal sinus, a fracture in the

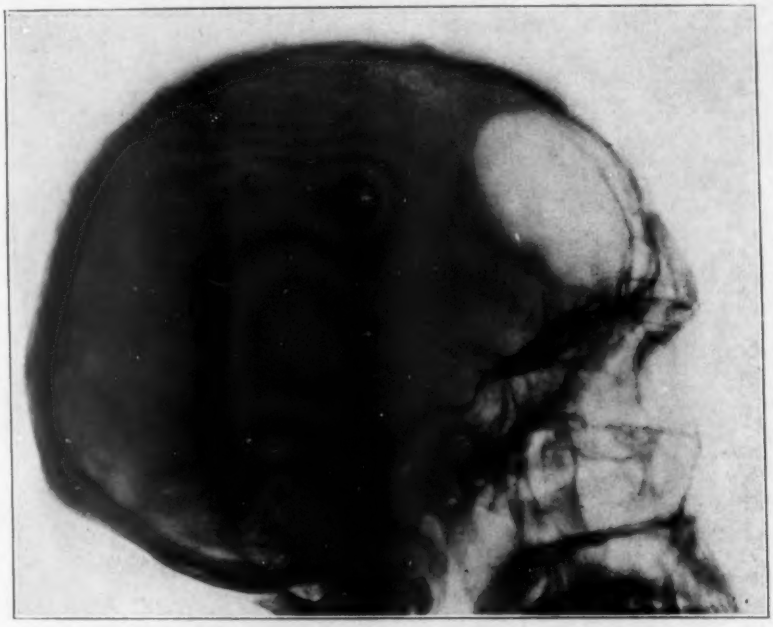

Fig. 16 (case 8).—Roentgenogram taken twenty-two days after injury showing a large pneumatocele in the right frontal lobe. A roentgenogram taken two days after injury failed to show air in this region.

posterior wall was disclosed and a corresponding rent in the dura was found. This rent measured approximately 1 cm. in length. It was not feasible to attempt repairing it by direct suture, fascia lata and muscle grafts being used for this purpose. He stood the operation well, but showed considerable mental confusion the following day. In short, for approximately two weeks he had periods when he was badly confused. He usually thought that he had been at home and had returned, or that there had been visitors other than the people who had actually called. Mental confusion occurred at times during the rest of his stay in the hospital. He returned to his home on August 11.

CASE 8.—*Extensive compound, comminuted depressed frontal fracture extending into the right frontal sinus and orbit. Depressed fragments elevated on day*

of injury. Appearance of cerebrospinal rhinorrhea, and traumatic pneumocephalus three weeks later. Operative closure of dural rent with muscle and fascia lata. Recovery.

C. E. E., aged 19, a messenger boy, was admitted to the Los Angeles General Hospital on July 5, 1929. A few hours earlier he had been injured in a collision between his motorcycle and an automobile. He was unconscious only a few minutes. At the time of admission his mind was perfectly clear. Examination revealed an extensive laceration crossing the forehead. Under this was a large depressed fracture of the frontal bone. The right eye was swollen shut. He was

Fig. 17 (case 8).—Roentgenogram taken twenty-two days after injury showing frontal fracture and pneumatocele in the right frontal lobe. The point of communication with the frontal sinus can be plainly seen.

taken to the operating room and the depressed fragments were brought up into place. The wound healed without infection. Within a few days, it was apparent that he was blind in the right eye, the pupil being widely dilated and failing to react to light. Examination of this fundus showed an enormous hemorrhage covering the nerve head and extending well into the macular region. The retina did not appear detached. The left fundus appeared normal.

A roentgenogram of the skull taken on July 7, two days after operation, showed a large irregular fracture of the frontal bone, involving the right frontal sinus. The fragments were in good position.

For the next three weeks the patient did quite well, except for recurrent nosebleed. No cerebrospinal rhinorrhea was noted. A complete ptosis of the right eyelid had developed, and an enophthalmos of the globe was apparent.

On July 26, he was transferred to the Santa Fe Hospital. About this time, cerebrospinal fluid began to leak through the right nostril. He also complained of considerable headache. The ptosis of the right eyelid began to disappear, but

Data on Eight Cases of Traumatic Pneumocephalus

Case	Age	Sex	Type and Location of Fracture	Duration of Time Following Injury Until Appearance of Pneumocephalus	Location and Extent of Pneumocephalus	Operative Procedure	Result
1	23	M	Depressed right frontal	Pneumocephalus appeared on day of injury	Right frontal lobe; ventricles partially filled	Fracture elevated; pneumocephalus discovered at operation; gradual absorption of air	Recovery
2	24	M	Depressed right frontal	Immediate appearance of cerebrospinal rhinorrhea; pneumocephalus developed four weeks later	Right frontal lobe	Not operated; pneumococcus meningitis developed	Death
3	13	M	Depressed right frontal	Pneumocephalus developed after five weeks, together with meningitis	Entire ventricular system and right frontal lobe	Fracture elevated; rent in dura not found; streptococcus meningitis demonstrated	Death
4	19	M	Linear, left frontal sinus	Pneumocephalus appeared after four weeks	Left frontal lobe; lateral ventricles	Explored; rent in dura repaired by suture and fascia lata graft	Recovery
5	23	F	Depressed frontal, bilateral	Pneumocephalus and meningitis appeared about a month after injury	Right frontal lobe	Fracture elevated; one dural rent sutured; second rent repaired by muscle and fascia lata graft	Recovery
6	41	M	Occipital and questionable right frontal	Immediate appearance of cerebrospinal rhinorrhea and pneumocephalus	Lateral ventricles and entire subarachnoid space	Not operated; pneumococcus meningitis developed	Death
7	44	M	Extensive comminuted frontal, bilateral	Cerebrospinal rhinorrhea developed one week; pneumocephalus seven weeks after injury	Right frontal lobe; lateral ventricles	Explored; dural rent repaired by fascia lata and muscle graft	Recovery
8	19	M	Extensive depressed frontal fracture involving right frontal sinus	Cerebrospinal rhinorrhea and pneumocephalus appeared about three weeks after injury	Right frontal lobe	Elevation of depressed fracture; exploration for pneumocephalus; dural rent repaired by suturing and fascia lata graft	Recovery

no vision in the eye was evident. The right fundus at this time showed an advancing optic atrophy. The retinal hemorrhage was fading. He showed no positive neurologic signs. Roentgen examination of the skull on July 27 showed the comminuted fractures of the frontal bone as before, but in addition a very large pneumocephalus of the right frontal lobe was seen (figs. 16 and 17).

Within a day or two the cerebrospinal rhinorrhea ceased, and the headache decreased. Further roentgenograms taken on August 6 showed that the amount of air in the frontal lobe had greatly decreased. The patient was observed for about ten days more. On August 14, he again noticed some fluid coming from the right side of his nose. He sneezed on one occasion and immediately experienced

an increase in his headache. At this time he was conscious of a sizzling sound in the right side of his head, probably when the air rushed in. Further roentgenograms of the skull showed a reestablishment of the original pneumocephalus.

On August 17, a scalp flap was turned back in the right frontal region exposing the fractured area. A fracture line was seen running through the anterior wall of the right frontal sinus, and through this fracture many bubbles of air gushed out. It was not feasible to attempt to turn a bone flap. Two of the larger fragments were removed, permitting retraction of the dura over the tip of the right frontal lobe. This membrane was found to be badly torn, and considerable laceration of the frontal lobe was seen. One was able to demonstrate a fracture line running down the posterior wall of the right frontal sinus. At one point an opening was present which permitted the passage of a probe directly into the sinus. It was impossible to suture the dura. A fascia lata graft was placed over the opening in the posterior wall of the frontal sinus, and muscle grafts covered the rent in the dura. The fragments of bone were replaced, and the wound was closed tightly.

The postoperative course was satisfactory, with stoppage of the cerebrospinal fluid leak and disappearance of headache. However, vision in the left eye did not return. The patient left the hospital on September 9 otherwise apparently well.

SUMMARY

Eight cases of traumatic pneumocephalus are reported. Three patients of this group died of meningitis, two of them succumbing from pneumococcus and one from streptococcus meningitis. Only one of these three patients was operated on, the operation being performed after meningitis had become general; in this instance, the tear in the dura was not found. Operation was performed in five cases with recovery; in each instance, the opening in the dura was found and closed, either by suture or muscle graft.

Any case of fracture of the skull communicating with an accessory nasal sinus, particularly the frontal, should be closely watched for the possible development of pneumocephalus. This complication may appear at once or more often several weeks after the injury. The presence of cerebrospinal rhinorrhea should increase precautionary measures. The patient should be warned against sneezing, coughing or any action that may intensify the air pressure in the accessory nasal sinuses. If pneumocephalus is demonstrated, whether the air is present in the frontal lobe, lateral ventricles or both, its removal should be attempted at once, together with closure of the dural rent. Signs of meningitis are often present, even in the absence of infecting organisms; consequently, they should not necessarily deter an attempt to correct the pneumocephalus. It may even be justifiable to proceed in certain cases in which infecting organisms have been demonstrated in the fluid. The prognosis in cases of pneumocephalus is probably better if operative rather than expectant treatment is used. Success depends largely on early recognition and prompt intervention.

EXPERIMENTAL SHOCK

THE CAUSE OF THE LOW BLOOD PRESSURE PRODUCED BY MUSCLE INJURY *

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The low blood pressure with which I am concerned in this paper is that which during and since the recent war has been recognized as "secondary shock." In contrast with this is the condition that has been termed "primary shock" or "collapse." A satisfactory explanation for the latter condition seems to have been offered by Goltz,[1] in 1863, when he found that a blow on the exposed mesentery of the suspended frog caused reflex inhibition of the heart through the vagus and a lessening of vascular tone generally throughout the body and especially in the abdominal cavity. As regards "secondary shock," many suggestions have been presented to account for the low blood pressure and other phenomena. The older ideas are enumerated in Groeningen's treatise,[2] while the more recent ones are described in detail in Cannon's monograph.[3]

Of the theories that have been advanced as to the cause of "secondary shock," the most divergent views have been expressed by those who maintain that it is associated with a general relaxation of the large vessels and those who maintain that it is accompanied by marked constriction of the arteries. Crile [4] and his associates have been the most arduous proponents of the former theory, which stipulates that prolonged sensory stimulation produces exhaustion of the vasomotor center, that a fall in the arterial blood pressure accompanies the exhaustion of the vasomotor center and that this produces an accumulation of blood in the large veins. Crile thought that this accumulation of blood in the large veins diminishes the diastolic filling of the heart and hence its output. Mapother [5] and later Malcolm [6] were among the first supporters of the second theory, which states that the arterioles are markedly con-

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* From the Department of Surgery, Vanderbilt University.

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5. Mapother: Brit. M. J. **2**:1023, 1879.
6. Malcolm: Tr. M. Soc., London **32**:274, 1909.

stricted in shock. It was believed by Malcolm that this constriction expressed plasma from the blood stream resulting in a diminution in the circulating blood volume. Most of the investigators subsequent to Malcolm have believed that there is a diminution in the circulating blood volume in shock, but there has been a great deal of disagreement as to what is responsible for this decrease. Starling [7] thought that most of the loss of circulating fluid is into the dilated capillaries of skeletal muscle. He explained the dilatation of capillaries by noting that the arterial blood pressure is usually higher during the exciting period which frequently precedes the injury. Most of the muscles usually become relaxed following a severe injury. The hypertonicity of the arteries and the hypotonicity of the muscles result in a slow flow of blood through the muscles and in an accumulation of blood there with a decrease in the circulating blood volume. Erlanger and his associates [8] reduced the volume of the circulating blood by manipulation of the abdominal viscera, by partial occlusion of the thoracic aorta or inferior vena cava, and by the injection of large amounts of epinephrine hydrochloride intravenously. In these experiments, they noted the distention of the capillaries and venules of the intestinal villi with red blood cells, but they stated, "The mechanism of the dilatation of the capillaries and venules has not been included in the scope of this investigation." The British Medical Research Committee in August, 1917, invited a Special Investigation Committee to work on surgical shock and allied conditions. This committee consisted of Bayliss, Bainbridge, Cannon, Richards, Sherrington, Starling, Dale and others. Their observations were published in "Report of Shock Committee, Special Report Series," nos. 25, 26 and 27. The work is summarized in Cannon's monograph.[3] The method which was employed in producing a low blood pressure, in many of the committee's experiments, consisted of traumatizing one of the posterior extremities of cats. They maintained that there was not sufficient bleeding into the wounds to account by itself for the reduction in pressure. Section of the cord in the upper lumbar region, in some experiments, showed that the fall in blood pressure was not due to any general effect of the trauma on the circulation, brought about by nervous agencies. It was assumed that the continued fall in pressure following trauma was produced by the absorption of some depressant substance. The effects of histamine and muscle trauma were compared in various experiments, and it was believed that the hypothetical depressant produced by injuring muscles was either histamine or some fairly closely related substance. The laboratory data were carefully correlated with

7. Starling: Arch. méd. belges. **71**:369, 1918.

8. Erlanger et al.: Am. J. Physiol. **49**:90, 151 and 345, 1919; **50**:31, 104, 119, 1919.

the clinical observations. This theory differs from the others, which consider loss of blood volume, vasoconstriction and capillary congestion as the essential disturbances in "secondary shock," in that evidence for the initiating agent is presented. However, it has in common with the other theories the fact that no initiating agent has actually been demonstrated.

There are many other theories which have been advanced in explanation of shock, each of which has at least a few proponents. Most of these do not emphasize the reduction in the circulating blood which has been definitely demonstrated by Keith [9] and others. These theories include: (1) the theory of inhibition, (2) the theory of fat embolism, (3) the theories of suprarenal hyperactivity and hypo-activity, (4) the theory of acidosis and (5) the theory of acapnia. All of them lack proof.

The experiments which are to be reported here were suggested by some work performed by Blalock and Bradburn.[10] The oxygen content of blood obtained from various veins was determined in shock, which was produced by several methods. It was found that the oxygen content of blood from the portal vein was much higher after a low blood pressure had been produced by trauma to the intestines than after a proportionate decline in pressure obtained by other methods. The oxygen content of blood from the femoral vein of a traumatized leg was high, while that from the opposite extremity was low. These observations together with others suggested but did not prove that a local accumulation of blood occurs in a traumatized area, and they were considered as evidence against the action of a histamine-like substance which produces a general bodily effect.

Trauma to one of the extremities of the experimental animal produces general phenomena that are closely similar to those seen in patients in shock. It has advantages over other methods of producing a fall in blood pressure in that the opposite extremity can be used as a control and in the fact that the inflow and outflow of blood from the part can be controlled as desired. As stated previously, this method was employed by Cannon and Bayliss [11] in their studies on traumatic shock.

The present study was undertaken in order to try to determine whether the low blood pressure produced by trauma to one of the extremities is due to the formation of some substance which exerts a

9. Keith: Report of Shock Committee, Medical Research Committee, no. 27, March, 1919.

10. Blalock and Bradburn: Blood Distribution in Shock: A Study of the Oxygen Content of the Venous Blood from Different Localities in Shock Produced by Hemorrhage, by Histamine and by Trauma, Arch. Surg. **20**:26, 1930.

11. Cannon and Bayliss: Note on Muscle Injury in Relation to Shock. Report of Shock Committee, Medical Research Committee, no. 26, pp. 19-23, March, 1919.

general bodily effect or whether it is due simply to hemorrhage locally. As the first approach, the experiments of Cannon and Bayliss were repeated. As sequelae, their experimental procedure has been altered in various ways.

METHODS

The experimental animals in all instances were dogs. Sodium-barbital, administered intravenously, was employed as the anesthetic. The amount given was 0.3 Gm. per kilogram of body weight. The anesthesia which was produced by this amount of barbital was sufficiently profound to permit of no evidence of pain when severe trauma was instituted. In several control experiments, the effect of barbital alone on the blood pressure was determined, and there was practically no alteration during the first five hours following its administration. In several animals, there was a rapid decline in the blood pressure shortly after the giving of barbital. These experiments were discarded.

The level of the mean blood pressure was used as the criterion of the degree of shock. This was determined by placing in the carotid artery a cannula which was connected to a mercury manometer. The pulse rate and the temperature were also determined frequently. When the room temperature was high or low, electric fans or warming pads were employed, in some instances, maintaining the temperature of the animal at approximately the normal level.

In all experiments in which the effects of trauma were determined, the injury was produced by striking one of the posterior extremities varying numbers of times with a hammer. The bones were not broken, and most of the blows were struck over the thick thigh muscles. This method of producing shock is almost identical with that described by Cannon and Bayliss.

At the conclusion of most of the experiments in which the effects of trauma were studied, the differences in weight of the posterior extremities were determined. It was found that trauma of sufficient severity to cause a low blood pressure produced an extravasation of blood not only into the tissues of the thigh, but also into the loose tissues of the groin and flank. This observation demonstrated the fact that an amputation at the upper part of the thigh would not determine the true difference in weight on the two sides. The site at which the amputations were performed was in the midabdominal region. The terminal aorta and vena cava were divided between ligatures after making a midline abdominal incision extending from the xyphoid process to the symphysis pubis. The symphysis pubis was divided with a saw. This gave ample exposure for the removal of the bladder and the rectum. The iliac vessels on each side were clamped. The lower part of the body was then removed from the upper by making transverse incisions in the midabdominal region at the same levels on the two sides. Transverse division of the spinal column with a saw completed the amputation. The lower part of the body was then divided into two equal halves by sawing longitudinally through the midline of the spinal column. The tail of the animal was then removed. Each of the two parts was placed in a vessel, the clamps were removed, and the weight of each half determined. There was practically no loss of blood during this procedure.

A sample of blood for a determination of the hemoglobin content was obtained before the animal was killed. After the posterior extremities were removed, an incision was made into the leg which had been traumatized, and a sample of the bloody fluid which was present there was obtained for a determination of the hemoglobin content. An attempt was then made to collect all of the blood from

the two posterior parts. Each of these was placed in a large basin. Multiple incisions were made through each, and every part was washed thoroughly with saline solution. The percentage of the hemoglobin of the fluid in the two basins was then determined. These figures when divided by the percentage of the hemoglobin of the blood and multiplied by the amount of fluid in the basins gave the amount of blood which was recovered from the two parts. A comparison of the percentage of the hemoglobin of blood from one of the vessels with that of the hemoglobin of blood from the tissues of the traumatized thigh gave an approximate idea as to the relative losses of red cells and plasma from the circulating blood.

The procedures other than those just mentioned varied in the different types of experiments and they will be described in detail along with the individual groups. The order in which these different groups of experiments is presented is the same in most instances as that in which they were performed. This is mentioned in order to show the manner in which one type of experiment suggested another.

OBSERVATIONS

1. *The Effects of Trauma to One Leg, No Tourniquet Applied: Is one able to produce a fall in blood pressure to a shock level without enough hemorrhage into the traumatized area to account for the decline?*

Eight experiments of this type were performed. Usually, approximately thirty minutes after the barbital was administered, the blood pressure was determined as a control. One of the legs was then traumatized by striking it a variable number of times with a hammer. The blood pressure fell during the initial part of the trauma, but if the trauma was continued for several minutes longer, it would usually rise. The rate of the fall of the blood pressure appeared to be almost directly proportional to the amount of injury which was inflicted. The length of time which elapsed between the initiation of the trauma and the reduction of the blood pressure to a shock level varied in the different experiments from one hour and fifteen minutes to six hours and twenty-eight minutes. Most certainly, this interval could have been either shortened or lengthened by increasing or decreasing the severity of the trauma. When the blood pressure reached a level of 80 mm. or below, there was always an evident increase in the size of the traumatized leg.

The amount of barbital which was given always caused a marked acceleration of the pulse rate. The rate usually declined after about an hour, even though the leg had been traumatized, and it reached a high level again when the blood pressure dropped. The temperature of the animal usually remained at approximately the same level throughout the experiment.

The mean blood pressure immediately before the amputation in the various experiments ranged from 9 to 94 mm. of mercury. In three of the experiments, the mean pressure was 80 mm. or above. In all the experiments, the difference in weight of the traumatized and non-traumatized sides indicated enough loss of fluid from the blood stream

to account for the reduction in the blood pressure to a shock level. If it is assumed that 1 liter (1,000 cc.) of blood weighs 1 Kg., the difference in the weights of the legs expressed in cubic centimeters of blood varied in the eight experiments from 530 to 960.

The eight animals varied in weight from 10.9 to 15 Kg. When a normal dog is bled 1 per cent of its body weight at hour intervals, the mean blood pressure is reduced to 70 mm. of mercury or below after from three to four hours. In all of the present group of experiments, the difference in weight of the two sides amounted to more than 4 per cent of the body weight. The fact that these animals were able to withstand a larger proportionate loss of blood volume when the bleeding was into the tissues of the leg than other animals could tolerate when

TABLE 1.—*The Effects of Trauma to One Leg, No Tourniquet Applied*

Experiment	Weight of Animal, Kg.	Control: Mean Blood Pressure, Mm. Hg	Time Interval Between Initial Trauma and Amputation	Mean Blood Pressure Immediately Before Amputation, Mm. Hg	Weight of Traumatized Part, Kg.	Weight of Nontraumatized Part, Kg.	Difference in Weight of Traumatized and Nontraumatized Parts, Kg.	Hemoglobin of Blood, per Cent	Hemoglobin of Fluid from Leg, per Cent	Amount of Blood of Traumatized Part, Cc.	Amount of Blood of Nontraumatized Part, Cc.	Difference in Amount of Blood of Traumatized and Nontraumatized Parts, Cc.
1	12.6	137	3° 21′	94	2.26	1.67	0.59	90	73	377	18	359
2	13.7	130	4° 34′	83	2.36	1.73	0.63	80	49	375	60	315
3	14.0	121	2° 41′	56	2.61	1.74	0.87	55	40	327	46	281
4	12.0	130	2° 20′	29	2.40	1.44	0.96	80*	..	655	23	632
5	12.5	139	6° 28′	58	2.32	1.79	0.53	80*	..	228	26	202
6	14.4	150	2° 0′	55	2.62	1.94	0.68	80*	..	557	24	533
7	10.9	157	3° 50′	9	1.72	1.18	0.54	60	..	391	24	367
8	15.0	120	1° 15′	80	2.70	1.96	0.74	70	..	529	49	470

* Estimate.

bled into a receptacle is explained by the fact that the percentage of the hemoglobin of the fluid from the leg was lower than that of the hemoglobin of the blood stream. This indicates a greater proportionate loss of plasma than of red cells. The results of the eight experiments are given in table 1.

The details of one experiment are given in full.

Protocol: Weight of dog, 14 Kg. At 9 a. m., barbital, 4.2 Gm., injected into the external jugular vein. At 9:32, control mean blood pressure, 121 mm. of mercury; pulse, 175; temperature, 101.2. From 9:35 to 9:50, trauma to the right posterior extremity with a hammer. At 9:53, blood pressure, 100. At 10, blood pressure, 101; pulse, 156. From 10:09 to 10:17, further trauma to leg. At 10:20, blood pressure, 96; pulse, 154; temperature, 100. At 10:49, blood pressure, 116. From 10:51 to 10:55, further trauma. At 10:56, blood pressure, 100; pulse, 128; temperature, 99.3. At 11:32, blood pressure, 100. From 11:35 to 11:40, further trauma. At 11:45, blood pressure, 78; pulse, 133; temperature, 99.5. At 12:06, blood pressure, 76. At 12:14, blood pressure, 56; pulse, 180. At 12:16, mid-abdominal amputation performed. The weight of each side and the amount of blood recovered from each are given as experiment 3 in table 1.

It is to be noted that in these eight experiments on dogs anesthetized by barbital, the blood pressure was not reduced to a shock level by trauma to the leg without causing the loss of enough of the blood volume locally to account for it.

2. Effects of Trauma to One Leg Which Has a Tourniquet Placed Tightly Around the Upper Part of the Thigh, Femoral Artery Not Included in Tourniquet: Is one able to produce shock? If so, is there enough hemorrhage to account for it?

Two experiments of this type were performed. After the animal was well anesthetized by barbital, the femoral artery was freed in the extreme upper part of the thigh for a distance of several centimeters. A strong rubber tube with a small circumference was placed beneath the artery. This tube was pulled tightly around the upper part of the thigh and anchored in place by two strong clamps. The leg was then traumatized distal to the tourniquet, care being taken to see that the tourniquet did not become dislodged so as to constrict the artery. In order to prevent the tourniquet from pressing on the artery, the foot was then tied to the arm of a ring stand, holding the leg upward and perpendicular to the body of the dog.

The blood pressure fell to a shock level in these two experiments after less trauma than was usually necessary in the experiments in which no tourniquet was used. Amputation and weighing of the posterior extremities showed enough difference in weight to account for the reduction in blood pressure.

The details of one experiment are as follows:

Protocol: Weight of dog, 16.7 Kg. At 8:55 a. m., barbital, 5.1 Gm., injected. At 9:20, blood pressure, 155; pulse, 163; temperature, 101.3. At 9:45, blood pressure, 152. At 10:03, tourniquet placed on tightly, artery outside. At 10:04, blood pressure, 154. From 10:10 to 10:18, trauma to the leg distal to tourniquet. At 10:25, blood pressure, 136. At 10:37, blood pressure, 140; pulse, 180; temperature, 102. At 10:55, blood pressure, 127. At 11:50, blood pressure, 98. At 12:10, blood pressure, 88; pulse, 180. At 12:17, blood pressure, 75. At 12:20, midabdominal amputation performed. Weight of traumatized part, 2.67 Kg.; of nontraumatized part, 1.96 Kg. Difference in weight, approximately 710 cc. of blood or plasma. Hemoglobin content of blood from the aorta, 65 per cent; of fluid recovered from traumatized leg, 52 per cent. Amount of blood recovered from traumatized side, 422 cc.; that of blood from nontraumatized side, 34 cc.

These experiments show that shock can be produced in an animal by traumatizing a leg which has a tourniquet around it, the artery being outside, and that there is enough loss of blood volume locally to account for the reduction in the blood pressure.

3. The Effects of Placing a Tourniquet Around the Upper Part of the Thigh, Femoral Artery Outside Tourniquet, No Trauma: Is a low blood pressure produced?

Five experiments of this type were performed. After the animal had been given barbital and the control studies had been made, the femoral artery was exposed in the upper part of the thigh. The tourniquet was placed around the leg beneath the artery. The blood pressure was determined at approximately half-hour intervals.

The leg distal to the tourniquet became swollen in less than an hour, but never increased in size as much as did the extremities which were traumatized with a tourniquet on. Throughout the course of the observations, the blood pressure declined slightly in two of the experiments, became slightly elevated in two, and remained the same in one. The longest period of observation was four hours, and the lowest mean blood pressure recorded, at the termination of the experiments, was 118 mm. of mercury.

These experiments show that leaving the femoral artery patent and tightly constricting the upper part of the thigh, without traumatizing the leg, does not result in the production of a low blood pressure.

Since a marked constriction of the upper part of the thigh with the femoral artery patent results in bleeding into the extremity and an increase in its size, but no marked reduction in blood pressure, it was wondered if the bleeding into two posterior extremities similarly prepared would cause a diminution in the blood pressure.

4. *Effects of Placing a Tourniquet Around the Upper Part of Each Posterior Extremity, with Femoral Arteries Outside and No Trauma: Is a low blood pressure produced?*

The procedures were exactly the same as those described for the aforementioned group, except that the two posterior extremities were employed instead of the one. Four experiments of this type were performed. Both legs became noticeably larger within an hour after the tourniquets were applied. The blood pressure declined to a shock level in all experiments. Incisions into the legs at the termination of the experiments showed much hemorrhage into the tissues.

Tourniquets applied tightly to both posterior extremities, the femoral arteries being left outside, cause a reduction in the mean blood pressure to 70 mm. of mercury or less.

It has been stated that the application of a tourniquet to one thigh excluding the artery causes little alteration in the blood pressure, while a similar procedure on both posterior extremities causes a decline. Histamine is believed to cause an increase in capillary permeability with a loss of fluid from the blood stream. It seemed desirable to determine whether or not the injection of histamine into the excluded femoral artery after a tourniquet had been placed around the thigh would alter the behavior of the blood pressure.

5. *Effects of Injection of Histamine into the Femoral Artery Which Is Outside of a Tourniquet Placed Around the Thigh, Segments of Femur Resected: Does the blood pressure behave in the same manner as in a similar procedure without the injection of histamine?*

The original idea in this group of experiments was to determine whether it was possible to produce a low blood pressure by injecting histamine into the femoral artery of a thigh which was surrounded by a tourniquet, the artery being outside. Previous experiments had shown that a low blood pressure was not produced when histamine was not injected. It was thought that this would give some information as to whether or not a histamine-like substance was responsible for part of the hemorrhage that occurs when a tourniquet circumscribes the structures of the thigh with the exception of the femoral artery.

In the first five experiments of this group, histamine was injected into the femoral artery distal to a bull-dog clip which was occluding the artery temporarily. The tourniquet had been placed around the thigh before the histamine was injected. The clip was placed on in order to guard against the back flow of histamine in the femoral artery. The amount of histamine injected, in most instances, was 10 mg. In three of the five experiments, there was an almost immediate decline in the blood pressure as soon as the histamine was injected. In one of the experiments there was a drop in the pressure as soon as the clip was removed from the artery, and in the remaining experiment the blood pressure was not altered by the injection of histamine. It was evident from these experiments that the placing of a tourniquet tightly around the thigh does not rule out the possibility of the absorption of toxic products from the part distal to the constriction. The most likely route for the return of the histamine into the general circulation was thought to be through the vessels of the femur.

In a series of eight experiments, approximately 5 cm. of the upper shaft of the femur was removed. The length of bone which was left attached to the head of the femur was about 7 cm. A tourniquet was then placed around the upper part of the thigh, the artery being excluded, and histamine was injected into the artery distal to a bull-dog clip. There was no marked change in the blood pressure in five of these experiments, and there was a definite decline in three. This indicated that there was still, in some instances, the possibility for the return of blood from the extremity.

In four experiments, an incision was made on the lateral surface of the upper part of the thigh over the greater trochanter of the femur. A Gigli saw was placed around the neck of the femur, and the neck was divided. Approximately 7 cm. of the upper part of the femur was then removed. This caused little loss of blood. Gauze was packed in

the cavity that resulted from removing part of the femur. The femoral artery was then dissected free in the groin, and a tourniquet was placed tightly around the upper part of the thigh. Histamine varying in amounts from 10 to 26 mg. was injected into the femoral artery distal to a bull-dog clip. No fall in blood pressure resulted. Neither did the removal of the clip from the artery result in any appreciable fall in pressure even when the observations were extended over a long period of time. The fact that the histamine remained in the leg was demonstrated by removing the tourniquet at the end of the experiment and noting the abrupt fall in the pressure. The fact that histamine causes no more fall in pressure when injected under the conditions enumerated than does the simple application of a tourniquet, excluding the artery, is demonstrated by comparing these experiments with those in which histamine was not injected. The results of a single experiment are given in detail.

Protocol: Weight of dog, 14.5 Kg. At 8:50 a. m., barbital, 4.3 Gm., injected. At 9:18, control studies, blood pressure, 116; pulse rate, 180; temperature, 103. At 9:27, blood pressure, 112. From 9:35 to 9:43, neck of femur divided; 7 cm. of upper part of femur removed. At 9:45, blood pressure, 107. At 9:50, tourniquet placed around upper part of thigh, femoral artery outside. At 9:51, blood pressure, 109. At 9:53, femoral artery occluded by a clip; 10 mg. histamine injected distal to the clip. At 9:54, blood pressure, 112. At 9:57, clip removed from femoral artery. At 9:59, blood pressure, 111; pulse, 180; temperature, 103. At 10:05, blood pressure, 110. At 10:30, blood pressure, 120; pulse, 180; temperature, 102.8. At 11, blood pressure, 128; pulse, 180. At 12:15, blood pressure, 123. At 1:20, blood pressure, 110; pulse, 180. At 1:25, tourniquet removed from around thigh. At 1:26, blood pressure, 35. At 1:33, blood pressure, 34.

Such results indicate that the extreme upper part of the femur must be removed in order to be certain that there will be no return of blood from the extremity which has a tourniquet around it. They also indicate that the injection of histamine into an extremity which is surrounded by a tourniquet, the artery being outside, does not alter the behavior of the blood pressure. This last statement is interpreted as meaning that there is as much loss of fluid from the blood stream under these conditions without the injection of histamine as there is with it.

In the previous experiments in which the effects of the application of a tourniquet to one or both legs were determined and also in the experiments in which the effects of trauma after applying a tourniquet were studied, the possibility of the absorption of toxins from the extremity was not eliminated. The repetition of these experiments after removing the upper part of one or both femora appeared to be indicated. The previous experiments were included in this report because the conditions attending their performance more nearly approach

the normal, since the removal of part of the femur is associated with a moderate amount of trauma. First, however, the effects of the simple removal of the upper parts of both femora were determined.

6. *Control Experiments on the Effects of Removal of a Part of the Femur on Each Side: Do the operations alone cause a fall in blood pressure?*

Two experiments of this type were performed. The length of the portion of the femur which was removed in each instance was about 6 cc. In one experiment, the mean arterial pressure was 140 mm. of mercury before the femora were resected, and the pressure was 130 mm. of mercury seven hours after the operation. In the second experiment, the mean arterial pressure was 110 mm. immediately preceding the operation, and it was 107 mm. six and and one-half hours later.

These experiments show that parts of the femora of dogs may be removed without causing a fall in blood pressure.

7. *Effects of a Tourniquet on Leg, Artery Outside, After Resection of the Upper Portion of One Femur, No Trauma: Does a fall in blood pressure result?*

The procedure in these experiments was the same as that in group 3, except that part of the femur was removed in the present ones. Four experiments of this type were performed. The duration of the application of the tourniquet varied in the different experiments from two hours and twenty minutes to four hours. There was practically no alteration in the blood pressure, there being a slight rise in two experiments and a slight fall in the remaining two.

In these experiments, as in those in which the femur was not resected, the application of a tourniquet to the thigh, the femoral artery being outside, did not cause a significant alteration in the blood pressure.

In two additional experiments, an amount of blood was allowed to flow from the carotid artery which equaled 1 per cent of the weight of the dog. The structures of the upper part of the thigh, with the exception of the femoral artery, were then constricted by a tourniquet. The mean blood pressure in one dog was 67 mm. after the tourniquet had been in place for five hours, and the other dog died two and one-half hours after the application of the tourniquet.

8. *Effects of Tourniquets on Both Thighs, Arteries Outside, After Resection of the Proximal Portions of Both Femora, No Trauma: Does a fall in blood pressure result?*

The results of the four experiments of this type were the same as those in group 4, in which tourniquets were applied to the thighs without removing parts of the femora on each side. In the first experiment, the mean blood pressure was 73 mm. of mercury two hours after

the tourniquets had been applied; in the second experiment, the pressure was 22 mm. two hours and seven minutes after the application of tourniquets, and in the third and fourth experiments the pressures were 72 and 77 mm. of mercury, respectively, three hours after the tourniquets were placed around the thighs.

These experiments show that the application of tourniquets to both posterior extremities, the femoral arteries being outside, results in a marked decline in the blood pressure.

9. *Effects of Trauma with Tourniquet on, Artery Outside, after Resection of the Upper Portion of One Femur: Does a fall in blood pressure occur? If so, is there sufficient hemorrhage to account for it?*

TABLE 2.—*The Effect of Trauma to One Leg, Femur Resected, Tourniquet Applied, Artery Outside*

Experiment	Weight of Animal, Kg.	Time Interval Between Initial Trauma and Amputation	Mean Blood Pressure Immediately Before Amputation, Mm. Hg	Weight of Traumatized Part, Kg.	Weight of Nontraumatized Part, Kg.	Difference in Weight of Traumatized and Nontraumatized Parts, Kg.	Hemoglobin of Blood, per Cent	Amount of Blood of Traumatized Part, Cc.	Amount of Blood of Nontraumatized Part, Cc.	Difference in Amount of Blood of Traumatized and Nontraumatized Parts, Cc.
1	18.2	3° 15′	84	3.12	2.20	0.92	..	...	..	...
2	10.4	2° 5′	45	2.04	1.61	0.43	74	247	8	239
3	9.7	1° 48′	25	2.08	1.65	0.43	80*	372	10	362
4	10.4	2° 12′	0 (dead)	2.98	2.23	0.75	..	...	..	...

* Estimate.

The procedure in these experiments was the same as that in group 2, except for the removal of the upper part of the femur. Four experiments of this type were performed. There was a definite decline in the blood pressure in all instances, and the difference in weight of the two extremities indicated sufficient loss of blood volume to account for the drop in pressure.

The results of these experiments are tabulated in table 2.

The details of one experiment are as follows:

Protocol.—Weight of dog, 10.4 Kg. At 9:25 a. m., barbital, 3 Gm., injected. At 9:40, control mean arterial pressure, 135 mm. of mercury; pulse rate, 120; temperature, 103.2. At 10:05, left femoral artery exposed; upper part of left femur removed. At 10:06, blood pressure, 137. At 10:11, tourniquet placed around upper thigh, artery outside. At 10:12, blood pressure, 135. From 10:14 to 10:20, trauma to the left leg distal to tourniquet. At 10:22, blood pressure, 150; pulse rate, 180; temperature, 103. At 11:05, blood pressure, 144. At 11:37, blood pressure, 135. From 11:39 to 11:44, trauma to left leg. At 11:46, blood pressure, 114; pulse rate, 185; temperature, 103. At 12:05, blood pressure, 64. At 12:12, blood pressure, 52. At 12:13, clip placed on femoral artery, and 12 mg. histamine injected distal to clip. At 12:15, blood pressure, 47. At 12:16,

clip removed from artery. At 12:20, blood pressure, 45. At 12:21, amputation performed. The figures for the differences in weight and amount of blood are given in table 2, experiment 2.

These experiments show that a low blood pressure can be produced by traumatizing one leg which is surrounded by a tourniquet, the artery being outside, and that the decline in pressure is due to the bleeding into the tissues distal to the tourniquet.

In the succeeding two groups of experiments, the effects of the reestablishment of the return circulation from the parts that had been occluded by tourniquets were determined.

10. *Effects of Removal of the Tourniquet from a Thigh the Femoral Artery of Which Had Not Been Occluded,* (1) *When No Trauma Had Been Inflicted and* (2) *When the Part Had Been Traumatized: Does the removal of the tourniquet cause a fall in blood pressure?*

These two types of experiments are reported together because their results are almost identical. In some experiments, the femur was not resected, while in others the upper part was removed. The results were the same whether a part of the femur was or was not removed. Eight experiments were performed. The tourniquet was left in place for periods of time varying from one hour and forty-four minutes to seven hours. The blood pressure declined in all instances on removal of the tourniquet, the greatest immediate fall being 30 mm. of mercury and the smallest fall 8 mm. The blood pressure was observed for periods varying from twenty minutes to three hours and forty-seven minutes following the removal of the tourniquet. In four of the experiments, it became elevated slightly, and in four experiments it continued to fall slowly.

In two additional experiments, the effects of releasing tourniquets which had been placed around both posterior extremities were determined. The femoral arteries were not included in the tourniquets, and the extremities were not traumatized. Removal of the tourniquets resulted in a definite fall in blood pressure in both experiments.

If a tourniquet was again placed around the leg after it had been left off for a while, the blood pressure would usually rise slightly. In one experiment, there was a definite fall in blood pressure following the replacement of the tourniquet.

Release of a tourniquet which had been constricting all of the structures of the upper part of the thigh with the exception of the femoral artery resulted in a fall in the blood pressure. The reason for this was not apparent. One possible explanation was that some toxic substance had been formed in the extremity which when liberated into the general circulation caused a fall in blood pressure. Another possibility, a view which will be analyzed, was that the removal of the

constriction allowed blood to flow into the tissues which had been compressed in the immediate vicinity of the tourniquet. These tissues had necessarily become anoxemic, and hyperemia almost certainly occurred when the constriction was released. An added possibility in the experiments in which trauma was produced was the likelihood that further hemorrhage would take place into the tissues which had been previously compressed by the tourniquet. It seemed desirable to have a method by which the blood could be allowed at will to return from the leg without removing the tourniquet. Isolation of the femoral vein in the groin as the femoral artery had been prepared in most experiments afforded this opportunity. The lumina of the femoral artery and vein could then be opened or closed as desired by a bull-dog clip.

11. *After the Femoral Artery and Vein Have Been Dissected Free in the Groin, the Vein Being Occluded by a Clip, and a Tourniquet Placed Around the Thigh Beneath the Two Vessels, a Study of the Effects of (a) Removal of the Clip from the Femoral Vein of One Leg Which Has Not Been Traumatized, (b) Removal of the Clips from the Femoral Veins of Both Posterior Extremities Which Have Not Been Traumatized, and (c) Removal of the Clip from the Femoral Vein of One Leg Which Has Been Traumatized: Does the removal of the clip from the vein cause a decline in the blood pressure?*

(*a*) The effects of removal of the clip from the femoral vein of a leg which had been constricted by a tourniquet were determined in two experiments. The upper part of the femur was removed before the tourniquet was applied, in one of these experiments, and the femur was left intact in the other. The thigh was constricted by the tourniquet for three hours, in one experiment, and five hours in the other, before the clip was removed from the vein. Removal of the clip from the vein resulted in a temporary rise in the blood pressure. The blood pressure then slowly declined and remained at approximately the level that existed before the clip was removed from the vein.

(*b*) The effects of removing the clips from the femoral veins of the two posterior extremities which had been constricted by tourniquets were determined in three experiments. The upper parts of the femora were removed in two of these. The results were approximately the same in all experiments. The blood pressure rose about 10 mm. of mercury as soon as the clips were removed from the veins. A slow drop in the pressure followed this initial rise, but the decline was no more rapid than that which had been taking place before the clips were removed. The veins were again occluded by clips after varying intervals of time, and no elevation of the blood pressure was observed.

The details of one experiment are as follows:

Protocol: Weight of dog, 17.8 Kg. At 8:40 a. m., barbital, 5.4 Gm., injected into external jugular vein. At 9:18, control blood pressure, 106; pulse, 150; temperature, 102.2. From 9:35 to 10, 7 cm. of upper end of each femur was removed. At 10:03, blood pressure, 112; pulse, 144; temperature, 101.8. At 10:12, tourniquets applied to both thighs; femoral artery and vein not occluded by tourniquet; femoral vein occluded by a clip. At 10:15, blood pressure, 118; pulse, 144. At 11, blood pressure, 133; pulse, 165. At 12, blood pressure, 108; temperature, 102.8. At 12:30, blood pressure, 94; pulse, 180. At 1, blood pressure, 80. At 1:14, blood pressure, 77; pulse, 180; temperature, 103. At 1:15, clips removed from the femoral veins. At 1:16, blood pressure, 88. At 1:20, blood pressure, 80. At 1:25, blood pressure, 76. At 1:30, blood pressure, 73. At 1:42, blood pressure, 68. At 2:01, blood pressure, 62; pulse, 195. At 2:25, blood pressure, 54; pulse, 185. At 2:46, blood pressure, 50. At 2:47, femoral veins occluded by clips. At 2:49, blood pressure, 47. At 3, blood pressure, 49. At 3:15, blood pressure, 45. At 3:30, blood pressure, 45. At 3:34, clips removed from veins; pulse, 190; temperature, 103. At 3:35, blood pressure, 56. At 3:40, blood pressure, 49. At 4, blood pressure, 46. At 4:30, blood pressure, 44.

(*c*) Eight experiments of this type were performed. The procedure in these experiments was as follows: The femoral artery and vein were exposed and freed in the groin. The upper part of the femur, approximately 7 cc., was removed. The femoral vein was then occluded by a bull-dog clip. In some of the experiments, the femoral artery was occluded temporarily by a clip. A tourniquet was then placed beneath the femoral artery and vein, and it was pulled tightly around the upper part of the thigh. The leg was then traumatized distal to the tourniquet with a hammer.

If the femoral artery, as well as the vein, was occluded by a clip during the traumatization and for a considerable period thereafter, there was no fall in the blood pressure until the occlusion of the artery was released. In fact, the blood pressure became elevated in all instances above that observed during the control period. When the clip was removed from the artery, the blood pressure declined rapidly at first and later more slowly.

After the blood pressure had been reduced by varying amounts as a result of the trauma, the clip was removed from the femoral vein. In six of the eight experiments, the behavior of the blood pressure was the same. There was an immediate small rise in the pressure as soon as the clip was removed from the vein, and after this there was a slow drop in the pressure. This decline in pressure was not so rapid as that which had been taking place before the occlusion of the vein was released. In three of the six experiments, the artery and the vein were occluded after the effects of releasing the occlusion of the vein had been determined. The blood pressure continued to fall in all of these.

The details of one of the six experiments follow:

Protocol: Weight of dog, 11.7 Kg. At 8:50 a. m., barbital, 3.6 Kg., injected. At 9:05, control blood pressure, 111; pulse, 192; temperature, 101.2. From 9:40 to 9:46, 6 cm. of the upper end of the left femur removed. At 9:50, blood pressure, 112. At 10, tourniquet on; artery and vein outside; artery and vein occluded by bull-dog clips. At 10:02, blood pressure, 111; pulse, 170. From 10:05 to 10:15, trauma to left leg. At 10:22, blood pressure, 131; temperature, 99.8; pulse, 180. At 10:24, clip removed from the femoral artery. At 10:27, blood pressure, 109. At 10:35, blood pressure, 85; pulse, 180; temperature, 100.8. At 10:42, blood pressure, 85. At 10:52, blood pressure, 90; pulse, 110. At 11:12, blood pressure, 94; pulse, 108; temperature, 101.3. At 11:32, blood pressure, 88; pulse, 115. At 11:50, blood pressure, 80. At 12:10, blood pressure, 68; pulse, 110; temperature, 101.4. At 12:14, blood pressure, 58. At 12:15, clip removed from the femoral vein. At 12:16, blood pressure, 64. At 12:20, blood pressure, 66; pulse, 110. At 12:22, blood pressure, 65; pulse, 110; temperature, 101.2. At 12:31, blood pressure, 55. At 12:39, blood pressure, 51; pulse, 170; temperature, 100.7. At 12:45, blood pressure, 52. At 12:47, blood pressure, 52. At 12:48, femoral artery and vein occluded. At 12:50, blood pressure, 52. At 12:53, blood pressure, 48; pulse, 180. At 1, blood pressure, 38; pulse, 205; temperature, 100.8. At 1:10, blood pressure, 38. At 1:25, blood pressure, 38. At 1:35, blood pressure, 34. At 1:36, clips removed from artery and vein. At 1:39, blood pressure, 38. At 1:51, blood pressure, 32. At 1:52, clips on femoral artery and vein. At 1:52½, 10 mg. histamine injected into femoral artery distal to the clip. At 1:55, blood pressure, 33. At 1:57, blood pressure, 32. At 1:58, clip removed from femoral vein. At 1:59, blood pressure, 11. At 2:01, animal dead; a midabdominal amputation performed. Weight of traumatized side, 2.01 Kg.; of nontraumatized side, 1.50 Kg. The difference in weight of the two sides, 0.51 Kg., corresponding to approximately 510 cc. of blood. Hemoglobin of blood, 62 per cent. Amount of blood recovered from traumatized side, 492 cc.; of that from nontraumatized side, 35 cc., a difference of 457 cc.

This experiment, which is typical of the other six, shows that the reestablishment of the venous return from the traumatized part, at least in these experiments, does not cause an acceleration of the fall in the blood pressure. The fact that the blood pressure did not fall when histamine was injected into the artery when the vein was occluded indicated that the tourniquet was preventing the return of any blood from the part. The fact that the animal died as soon as the clip was removed from the vein after the histamine had been injected, indicated that the vein was still capable of transporting blood from the extremity back into the general circulation. A record of the blood pressures which were obtained in this experiment is given in figure 1.

As stated previously, there was an immediate decline in the blood pressure when the clip was removed from the vein in two of the eight experiments. In one of these, the pressure dropped rather slowly, and the animal lived for more than two hours after the occlusion of the vein was released. In the other experiment, the animal died nine minutes after the clip was removed from the vein. The mean blood

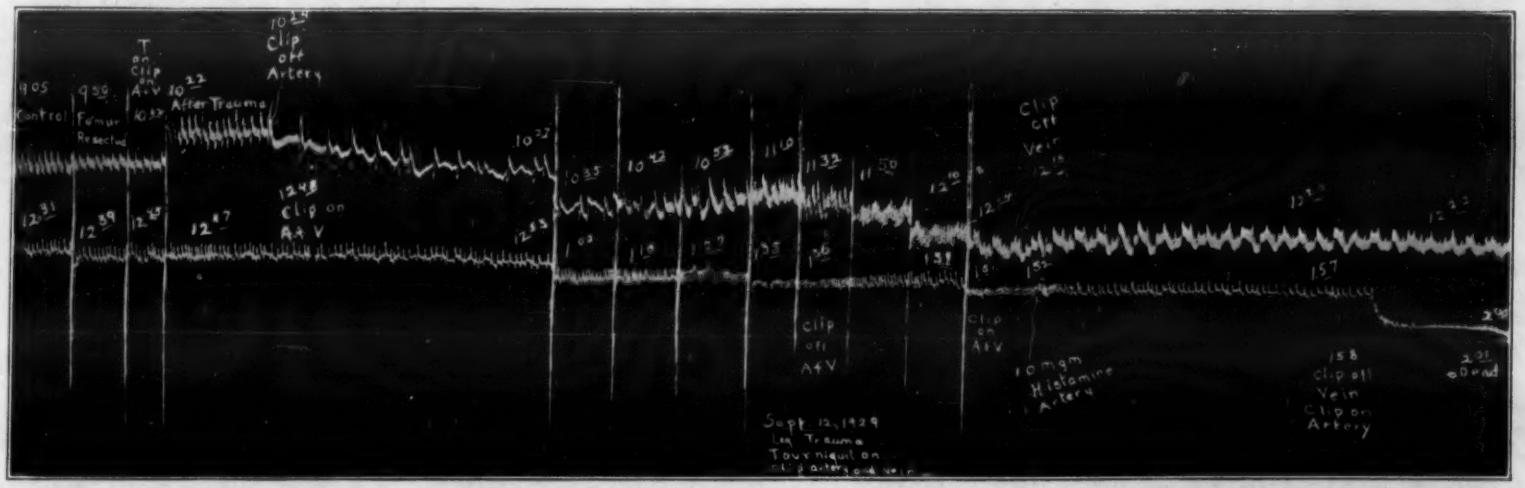

Fig. 1.—Effects of releasing the occlusion of the femoral vein of a leg which had been traumatized. The experiment extended from 9:05 a. m. to 2:01 p. m. The numerals indicate the times at which the blood pressure was determined. The curve reads from left to right. *T* stands for tourniquet, *A* for artery and *V* for vein.

pressure had been 74 mm. of mercury immediatley before the vein was released. The reason for the sudden death was not determined. The mean blood pressure had dropped from 144 to 74 mm. of mercury during the fifty-four minutes preceding the release of the venous occlusion, but even with such a rapid decline, it is not likely that the sudden death was due to hemorrhage alone. It is possible that sodium citrate was forced into the artery when the arterial cannula was washed out four minutes prior to the termination of the experiment. It is also possible that a toxic substance was formed in the injured area which when liberated into the general circulation caused death.

The great majority of the experiments in this group indicate that the reestablishment of the venous return from an extremity which is constricted in its upper part, except for the artery and vein, does not cause a more rapid decline in blood pressure than would have been expected had the vein remained occluded. The same results were noted in the experiments in which traumatization was an added factor.

12. *The Effects of Occluding the Terminal Aorta and Vena Cava after the Arterial Blood Pressure Has Been Reduced by Traumatization of One Posterior Extremity: What effect has this on the blood pressure?*

The terminal aorta and vena cava were occluded in seven experiments in which the blood pressure had been reduced varying amounts by traumatization of one posterior extremity. The level of the mean arterial pressure just prior to the occlusion varied in the different experiments from 106 to 44 mm. of mercury. The blood pressure continued to fall in four of the experiments, became elevated in two, and remained stationary in the other experiment.

Cannon and Bayliss [12] reported the experimental production of a low blood pressure in cats by occlusion of the terminal aorta for one hour. The repetition of this experiment on dogs was the next step undertaken.

13. *The Effects of Occlusion of the Terminal Aorta for One Hour: Is a low blood pressure produced by releasing the occlusion?*

The terminal abdominal aorta was occluded for one hour by a ligature and a bull-dog clip in each of three experiments. During the period of occlusion, the blood pressure either rose slightly above that observed during the control period or remained approximately the same. In one experiment, following the release of the occlusion of the aorta, the blood pressure remained at approximately the same level as that observed during the control period, in one it was slightly higher, and in the remaining experiment it was slightly lower.

12. Cannon and Bayliss (footnote 11, page 21).

The details of one experiment are as follows:

Protocol: Weight of dog, 9.1 Kg. At 8:50 a. m., barbital, 2.9 Gm., injected. At 9:31, control mean blood pressure, 118. At 9:37, the terminal aorta occluded. At 9:38, blood pressure, 133. At 10:30, blood pressure, 145. At 10:45, blood pressure, 145. At 10:46, occlusion of the aorta released. At 10:50, blood pressure, 129. At 10:57, blood pressure, 116. At 11:10, blood pressure, 116. At 11:30, blood pressure, 116. At 11:42, blood pressure, 115. At 12, blood pressure, 122.

In three experiments, the effects on the blood pressure of occlusion of the terminal inferior vena cava for an hour were determined. The alteration in blood pressure which accompanied this procedure was less than that which attended the closing and opening of the aorta.

Occlusion of the terminal abdominal aorta or inferior vena cava of the dog for an hour did not result in the production of a low blood pressure.

Cannon and Bayliss[18] found that massage of a damaged muscle results in a further fall in the blood pressure. This experiment was repeated and supplemented in the next group of observations.

14. *The Effects of Massage of the Traumatized and Nontraumatized Legs: What effect does massage have on the level of the blood pressure?*

The effects of massaging the leg which had been traumatized and of massaging the opposite extremity which had not been traumatized were determined many times in several experiments. In almost all instances, massaging either extremity caused a fleeting reduction in the blood pressure. The greater decline in pressure resulted from massage of the extremity which had been traumatized. When the nontraumatized extremity was massaged first, it caused almost as great a decline in pressure as did massage one minute later of the traumatized extremity. When the traumatized extremity was massaged first, the decline in the pressure was definitely greater than that which resulted from subsequent massage of the leg which had not been traumatized. The figures for the decline in pressure expressed in millimeters of mercury throughout the course of one experiment are as follows: Nontraumatized 15, traumatized 18; traumatized 22, nontraumatized 15; nontraumatized 24, traumatized 28; traumatized 30, nontraumatized 13; nontraumatized 14, traumatized 16. A record of the blood pressure which shows the effects of massage is presented in figure 2.

In two additional experiments, the upper part of one femur was removed, and a tourniquet was placed around the upper part of the thigh. The femoral artery was not included in the tourniquet. No trauma was instituted. After more than an hour, first one extremity

13. Cannon and Bayliss (footnote 11, page 22).

and then the other was massaged. In one experiment, massage of either of the posterior extremities caused a reduction in the blood pressure. The decline was slightly greater on the side that was not occluded by a tourniquet. In the other experiment, there was no definite reduction in the pressure which was caused by massage of either extremity.

These experiments show that massage of either the traumatized or the nontraumatized extremity usually causes a temporary reduction in

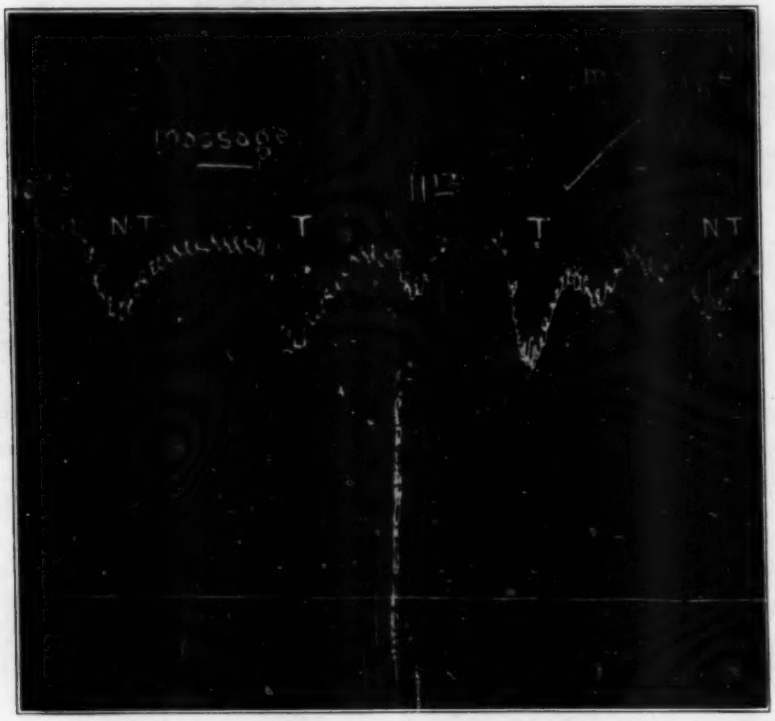

Fig. 2.—Effects of massage of the traumatized and nontraumatized extremities. The curve reads from left to right. *T* stands for the traumatized extremity and *NT* for the nontraumatized one.

the blood pressure, the greater decline occurring after massage of the traumatized side.

An attempt was next made to obtain further evidence of the presence or absence of a depressor substance by transfusion experiments.

15. *The Effects of the Injection of Blood from Dogs in Which the Blood Pressure Had Been Lowered by Trauma to an Extremity into (a) a Normal Dog, (b) a Dog in Which the Blood Pressure Had Been Lowered by Hemorrhage, and (c) a Dog in Which the Blood Pressure*

Had Been Lowered by Trauma to an Extremity: What effect has the injection on the blood pressure?

(*a*) The donor in this instance had had one leg traumatized to a moderate degree at infrequent intervals during the twenty-four hours preceding the transfusion. The blood pressure at the time was 45 mm. of mercury systolic and 32 mm. diastolic. All of the blood which was obtainable was taken from this dog and defibrinated. The total amount was 325 cc. At 3:30 p. m., the blood pressure of the recipient was 120 systolic and 85 mm. diastolic. At 3:32, transfusion into the external jugular vein was begun. At 3:34, 200 cc. of blood had been injected, and the blood pressure of the recipient was 144/100. At 3:36, with transfusion completed, the blood pressure was 140/110; at 3:41, 118/75; at 4:00, 115/76, and at 4:30, 130/80.

(*b*) The donor in this experiment had had the blood pressure reduced to 75 mm. of mercury, systolic, and 67 mm., diastolic, by trauma to one extremity. Approximately 200 cc. of blood was obtained from this dog, and following the injection of saline solution, an additional 300 cc. of blood was withdrawn. The blood was defibrinated and kept. warm. The recipient weighed 10.5 Kg. At 4:30 p. m., barbital, 3.5 Gm., was given. At 5:30, the control blood pressure was 150 mm. of mercury, systolic, and 110 mm., diastolic. From 5:30 to 5:33, the animal was bled 300 cc. At 5:34, the blood pressure was 25 mm., systolic, and 20 mm., diastolic. From 5:35 to 5:38, 500 cc. of blood which had been obtained from the traumatized dog was allowed to run into the external jugular vein of the recipient. At 5:38, the blood pressure was 170/150; at 5:45, it was 120/86; at 5:55, 130/90; at 6:03, 140/90; at 8:40, 14 hours later, 144/100.

(*c*) A low blood pressure was produced in two dogs by trauma to the posterior extremities. The dogs each weighed 8 Kg. At 12:28 p. m., the mean blood pressure of dog A was 50 mm. of mercury and that of dog B was 51 mm. At 12:29, the proximal end of the carotid artery of dog B was connected to the proximal end of the external jugular vein of dog A. At 12:31, the blood pressure of dog A was 90. At 12:34, dog B died. At 12:34, the blood pressure of dog A was 93. At 12:37, the blood pressure of dog A was 88. At 12:55, the blood pressure of dog A was 72. At 1:17, the blood pressure of dog A was 67. The experiment was discontinued. Dog B died shortly after its artery was connected to the vein of dog A, and it is likely that the amount of blood that passed from B to A was not great.

No evidence for the existence of a depressor substance in the blood of a dog in which the blood pressure had been reduced by traumatization was found in these transfusion experiments.

16. *The Effects on the Macroscopic and Microscopic Appearance of the Gallbladder of (1) the Intravenous Injection of Histamine, and (2) Trauma to an Extremity: Is an alteration in the appearance of the gallbladder produced by either one or both of these procedures?*

Bradburn and Blalock [14] found that the intravenous injection of histamine in amounts sufficient to produce a sustained lowering of the blood pressure causes changes in the gallbladder. The usual bluish appearance of the gallbladder is lost and it assumes a whitish color. The walls of the gallbladder become thickened; the gallbladder decreases in size and contains less bile. Microscopic examination shows a great deal of edema. No alteration in the appearance of the gallbladder was produced in any of the experiments reported here, except those in which histamine was injected.

Injection of histamine causes alterations in the gallbladder. Trauma to an extremity produces no such change.

COMMENT

"A primary consideration in the experimental study of natural phenomena is that the reproduction of the phenomena under controllable conditions shall resemble as closely as possible the occurrences in nature." This statement quoted from Cannon [15] expresses the opinion held by Cannon and Bayliss [12] to the effect that the circumstances which attend the experimental production of shock by trauma to extremities are more closely comparable with those in some cases of shock in man than those when a low blood pressure is produced by other methods. It is certain that no operation on the intestinal tract of the human being is associated with as much trauma as is necessary for the experimental production of a low blood pressure by intestinal manipulation. It is extremely difficult to produce shock experimentally by injury to the central or peripheral nervous system. A low blood pressure is comparatively easily produced experimentally in animals by traumatizing large areas of muscle. This method lends itself to controllable conditions more readily than any other. The method is objectionable as are all means in which gross injury of tissue is produced, in that the experiments must be performed on animals that are continually anesthetized or on decerebrate animals.

Many comparisons will be made in this discussion between the results reported here and those obtained by the "Shock Committee," Cannon and Bayliss, in particular. Attention will be focused largely on the "toxemia theory of shock," because most of the recent experi-

14. Bradburn and Blalock: Unpublished results on the effect of histamine upon the gallbladder.

15. Cannon (footnote 3, page 142).

mental work has supported it and because my personal opinion before undertaking this work was that it offered the most satisfactory explanation for the initiation of events leading to the production of a low blood pressure and the associated observations. This opinion is not supported by the experimental work herein reported.

The experiments of Cannon and Bayliss [11] were performed on cats anesthetized by ethyl carbamate (urethrne). An iron block was placed at one side of the thigh, and the flexor group of muscles was struck six or seven times with a hammer, "so that they were ruptured and severely bruised." In most instances, the skin was not broken, and the femur was not fractured. Regarding the condition which was produced by the traumatization, they stated, "As time passed after the traumatization, the muscles underwent much swelling; and at autopsy there we found varying amounts of extravasated blood. In no case, however, was there sufficient bleeding into the wounds to account, by itself alone, for the effects observed." The amount of bleeding into the injured extremity was determined by Cannon and Bayliss by removing the two hind limbs by symmetrical cuts and weighing them. In the experiments which were performed at a later date by Cannon,[16] dogs and rabbits, as well as cats, were used. Ether was employed as the anesthetic in these experiments, and the amount of ether which was used was reduced after the blood pressure had reached a fairly low level. Cannon stated, "The development of the low blood pressure after tissue injury was proved not to be due to loss of fluid from the systemic circulation, by carefully skinning the posterior extremities after death, disarticulating the legs at the knee and removing the thighs at the hip by symmetrical cuts through the tissues; the thighs were then weighed." He found that the difference in weight of the two sides was as low as 11 per cent of the estimated weight of the blood of the animal.

The results of the experiments reported here are seemingly contrary to those of Cannon and Bayliss.[11] The reason for this discrepancy is not apparent, as the methods which were employed in producing the decline in blood pressure are almost identical. The most likely explanation for the discrepancy is believed to be that it is due to the difference in the methods which were employed in the determination of the weights of the traumatized and nontraumatized parts. The two extremities were amputated by Cannon and Bayliss by symmetrical cuts across the thighs. There are several objections to this method. It is impossible to be sure that the level of the amputation is the same on the two sides because of the thick layers of muscle there and because of the irregular contour of the thigh. After a thigh has been traumatized severely, it is not

16. Cannon: Some Characteristics of Shock Induced by Tissue Injury. Report of Shock Committee, Medical Research Committee, no. 26, p. 27, March, 1919.

possible to cut across it without the loss of some blood. Trauma to a thigh results in some bleeding into the loose tissues of the groin and flank, and this blood is not included in the amputated part when the incision is made across the upper part of the thigh. These objections were overcome in the present experiments by performing the amputation in the midabdominal region after ligation of the abdominal aorta and vena cava and clamping of the iliac vessels on both sides. In control experiments in which no trauma was instituted, the weights of the two parts were practically identical. The difference in weight of the parts in all experiments in which a low blood pressure was produced by trauma to one extremity amounted to at least 4 per cent of the body weight or almost half of the calculated blood volume. The level of the mean arterial pressure at the time of amputation in three experiments was 80 mm. of mercury or above, which indicates that hemorrhage initiates and is not one of the subsequent events in the declining blood pressure.

In some of the experiments of Cannon and Bayliss,[11] the spinal cord was transected above the lumbar plexus so that all the nerves to the leg which was to be injured were severed. Trauma to the denervated extremity then resulted in changes similar to those obtained in experiments in which the nerve supply was intact. Cannon and Bayliss stated, "The chief interest of the results obtained lies in the demonstration that they are not due to nervous reflexes but to the absorption of some toxic substances given off by the injured tissues." It did not seem necessary to repeat these observations in the present experiments because hemorrhage was sufficient to account for the reduction in blood pressure in the presence of an intact nerve supply and it most certainly would have been sufficient in a denervated extremity.

The experiments which were performed by Cannon and Bayliss were later repeated by Bayliss.[17] He found that a low blood pressure could not always be produced in strong healthy cats by traumatization of an extremity. He removed 15 per cent of the blood volume of cats in which the blood pressure had been reduced by traumatization, but in which a spontaneous recovery was apparently taking place. The blood pressure was lowered greatly by the loss of blood, and he stated, "The loss of this amount of blood is rapidly recovered from by the uninjured cat." However, this is not proof of the presence of a depressor substance, since bleeding a dog of 15 per cent of its blood volume produces a low blood pressure, provided there has been a considerable amount of blood lost previously. This was demonstrated in some of the experiments reported here. The tight application of a tourniquet to the

17. Bayliss: Further Observations on the Results of Muscle Injury and Their Treatment. Report of Shock Committee, Medical Research Committee, no. 26, pp. 23-26, March, 1919.

upper portion of the thigh, after the upper part of the femur has been removed and the femoral artery has been placed outside the constriction, causes little alteration in the level of the blood pressure. If before the tourniquet is applied, blood is removed from the animal which amounts to 1 per cent of its body weight or approximately 15 per cent of its blood volume, the blood pressure usually falls to a low level after the tourniquet has been in place for a long while. This decline in blood pressure takes place without any gross trauma and without the possibility for the return of any depressant substance from the extremity. The absence of any return of blood from the extremity was demonstrated when the injection of histamine into the femoral artery produced no alteration in the blood pressure. A similar fall in blood pressure was obtained without inducing external hemorrhage by constriction of both thighs by tourniquets by the method described. Here, again, there was neither trauma nor possibility of the return of depressant substances from the extremities. A low blood pressure was produced by traumatization of an extremity distal to a tourniquet which constricted all the structures of the upper part of the thigh, except the femoral artery. The upper part of the femur was removed in most of these experiments, and the injection of histamine indicated that there was no return of blood from the part. Amputation and weighing of the extremities showed that there was enough loss of fluid from the blood stream into the traumatized leg to account for the reduction in the blood pressure.

Cannon [16] found that the blood pressure failed to fall at the usual time following muscle injury if the blood vessels to the injured area were tied. These observations were confirmed in the present experiments. In one of these, the thigh was constricted by a tourniquet, and the femoral artery and vein were occluded by clips for almost five hours following the initiation of the trauma. The blood pressure was higher at the end of this period than it had been before the leg was traumatized. In one of Cannon's experiments, the occlusion of the vessels was released thirty-three minutes after the traumatization, and a fall in blood pressure resulted. He stated, "The experiment just mentioned (fig. 2) indicated that some substance given off from the injured tissue was the cause of the drop in pressure, for the permanent fall occurred only where the blood was permitted to flow in and out of the damaged region, thirty-three minutes after the traumatism." The present experiments have indicated that it is not necessary to have the blood flowing out of the damaged region in order to obtain a decline in the blood pressure. The presence of a patent femoral artery which allows the hemorrhage to take place is all that is necessary. The experiment reported by Cannon in which the occlusion of the arteries and veins was released did not indicate necessarily that the decline in pressure was due to some depressant substance given off by the injured

tissue, for hemorrhage occurs after trauma in the presence of a patent artery regardless of whether the veins are or are not occluded. In further experiments, Cannon [16] ligated the blood vessels of an extremity after a low blood pressure had been produced by traumatization. He found that the blood pressure might begin to rise after the vessels were ligated and that the pressure, in some instances, reached the level which existed before the trauma. It is known that hemorrhages of moderate severity are followed by a dilution of the blood in an attempt to restore the blood volume to the previous level. In the experiments in group 12, described in this paper, the terminal aorta and vena cava were ligated after the blood pressure had been reduced varying amounts by trauma to an extremity. The effects of this procedure were variable; in some instances there was a continued decline and in others a rise in the blood pressure. The impression was gained that the behavior of the blood pressure depended on whether or not a dilution of the remaining blood volume took place. If the decline in the blood pressure were due entirely to the action of some toxin, then the blood pressure would probably rise in all instances when the pathway for the return of this toxin into the general circulation was occluded, provided that the pressure had not been reduced to a low level for a long period of time. Evidence for this was not obtained in the present experiments. As regards the spontaneous rise in the blood pressure which may occur after small amounts of trauma, Cannon stated, "If the tissue damage has not been too great, the pressure may fall to less than 100 mm. of mercury, and then spontaneously rise to the former level. This result seems to indicate that the toxic material is limited by the amount of injury, and that after it has produced its depressant effect the pressure rises because no more of the material is being produced." The present work indicates that the following would constitute a more likely explanation. Trauma of sufficient severity to the anesthetized dog to cause a decline in blood pressure produces an extravasation of blood and fluid into the injured tissues. The amount of hemorrhage is controlled by the amount of the injury which is inflicted. The rapid loss of part of the circulating blood volume causes a reduction in the blood pressure. The blood volume increases owing to dilution of the blood after the hemorrhage has stopped, provided that the blood pressure has not reached too low a level. The increase in blood volume results in an increase in the blood pressure.

Cannon and Bayliss [11] found that a marked reduction in the blood pressure occurred when a clip which had been occluding the terminal abdominal aorta for an hour was removed. In the one experiment which they report, the terminal aorta of a cat under urethane anesthesia was occluded for sixty-two minutes. The average blood pressure dropped

to 65 mm., shortly after the clip was removed. After twenty minutes, it had risen to 82 mm., and it remained at this level for forty-five minutes. They stated, "This experiment shows that the material swept out of a muscular portion of the body by the returning blood contains various metabolites which lower the blood pressure." With a procedure similar to theirs three experiments were performed on dogs, and the results are reported in the paragraphs dealing with group 13. The aorta was occluded for the same length of time. The difference in the two procedures is that the experiment reported by Cannon and Bayliss was performed on a cat anesthetized by ethyl carbamate, while the experiments reported here were performed on dogs anesthetized with barbital. The results were different. The blood pressure rose above the level observed during the control period when the aorta was occluded. Following the release of the occlusion, the blood pressure assumed a level which was approximately the same as that observed during the control period. These experiments present no evidence for the formation of a toxic material as a result of the temporary suppression of the blood supply. The small alterations in the blood pressure on release of the occlusion may be due to a dilatation of the vessels of the posterior extremities as a result of the local lack of oxygen that had been present.

It was found in the experiments in group 10 that the removal of a tourniquet which had been occluding all of the structures of the upper part of the thigh except the femoral artery resulted in at least a temporary reduction in the blood pressure. This alteration in the pressure occurred whether the leg had or had not been traumatized. It was believed that the most likely explanation for the decline in pressure was either that it was due to the passage of some depressant substance from the traumatized part into the general circulation or that it was due to the filling up with blood of the vessels which had been compressed in the immediate neighborhood of the tourniquet. Even though a narrow tourniquet was used, its application around the thickest part of the thigh rendered a rather large mass of muscle practically bloodless. It would seem that the amount of blood which would return from the femoral vein of the leg in which stasis had been produced would more than compensate for the return of blood to the part which had been rendered anemic. It was thought that information could be gained as to whether the decline in pressure was due to the absorption of some toxic substance or to a local alteration in the circulation by changing the experimental procedure so that the femoral vein could be occluded or opened as desired and the tourniquet could be left in place. This was done by placing the femoral vein as well as the femoral artery outside the tourniquet. Release of the occlusion of the femoral vein after the

tourniquet had been in place for varying periods of time resulted in a temporary rise in the blood pressure in six of the eight experiments. After this initial rise, the blood pressure declined no more rapidly than before the clip was removed from the vein. The patency of the vein was demonstrated by the injection of histamine into the femoral artery at the termination of the experiment. It is believed that the decline in blood pressure which followed the removal of the tourniquet was not due to the action of some depressant substance, because if it were, a similar result should have followed restablishment of the circulation through the femoral vein of a leg which was occluded by a tourniquet.

Cannon and Bayliss [11] found that massage of muscles which had been injured caused a further fall of the blood pressure. They state, "In connection with the facts given above, it is of interest to note that massage of damaged muscles, unless a nerve happens to be pinched, results in a further fall of blood pressure. The phenomenon has probably some significance in relation to the increase of shock produced in cases of fracture of the femur when the limb is not adequately supported during transit to the casualty cleaning station." It was found in the present experiments that massage of a traumatized extremity usually causes a fall in blood pressure, but the decline is only a momentary one and a drop is obtained by massage of the opposite normal extremity. The decline is usually greater when the traumatized part is massaged. The fact that the pressure declines temporarily when either extremity is massaged is believed to indicate that the massage in some way alters the caliber of the vessels locally with a resultant change in the arterial pressure. The movement of a broken femur may in some ways simulate manual massage of traumatized tissues. However, it seems more likely that the deleterious effects are due to further bleeding caused by injury to the soft tissues near the sharp bone fragments.

The transfusion experiments which are reported here corroborate the observations of Smith,[18] who performed similar experiments. He ligated the femoral artery and vein of one leg and then traumatized it. One hour and fifteen minutes after the traumatism, the clip was removed from the femoral artery and 25 cc. of blood was withdrawn from a branch of the distal end of the clamped vein. The blood pressure fell 20 mm. of mercury. The blood was then injected into the femoral vein of the opposite side, and the blood pressure rose to the original level. In another experiment, blood was obtained from a femoral vein of a traumatized extremity and injected into the femoral vein of a dog which had been bled 15 per cent of the calculated blood volume. He stated, "The transfused blood failed to produce any appreciable effect in

18. Smith, M. I.: Studies on Experimental Shock with Especial Reference to Its Treatment, J. Pharmacol. & Exper. Therap. **32**:465, 1927-1928.

the recipient." Neither the experiments of Smith nor those which are reported in this paper prove that a depressant substance is not present in small amounts in the blood obtained from the traumatized part. The effects due to increasing the blood volume of the recipient may overbalance the action of a depressant substance, if such is present. However, neither do they present evidence that a toxin is present.

McIver and Haggart [19] performed cross-circulation experiments in an effort to determine if trauma to muscles gives rise to a substance that lowers the blood pressure. The posterior extremities of one cat were traumatized after ligation of its abdominal aorta and vena cava. A mid-abdominal amputation was then performed on this animal and the distal parts of the abdominal aorta and vena cava were connected to the proximal aorta and vena cava of a cat with a normal blood pressure. The blood pressure of the latter animal in most experiments declined to a shock level within thirty minutes. No conclusions can be drawn from these experiments because the aorta and vena cava of the first cat were ligated before the trauma was instituted. This allowed the second cat to bleed into the traumatized extremities of the first one after the anastomoses were made. An effort was made to repeat these experiments, the extremities being traumatized before ligation of the aorta and vena cava. The attempts failed because of clots that formed in the cannulas connecting the venae cavae.

Many statements are found in the reports by physiologists and clinicians published during and immediately after the war concerning the importance of differentiating between "shock" and "hemorrhage." As regards the observations in "shock," Cannon, Fraser and Hooper [20] stated, "In cases of shock as seen at a casualty clearing station in conditions of warfare, the red count of blood taken from various capillaries is higher than that of blood taken from a vein. The discrepancy is greater, the more profound the shock, and not infrequently is as much as two million corpuscles per cubic millimeter. Since the venous count is approximately normal, the condition is due to a stagnation of corpuscles in the capillaries. The observations by means of blood counting have been confirmed by hematocrit and hemoglobin determinations." In regard to "hemorrhage," they stated, "After hemorrhage, and in cases of shock complicated with hemorrhage, the hemoglobin reading is relatively low compared with the red count." It is undoubtedly true that hemorrhage outside the body in moderate amounts results in a dilution of the blood. The experiments in group 1 which are reported in this

19. McIver, M. A., and Haggart, W. W.: Traumatic Shock; Some Experimental Work on Crossed Circulation, Surg. Gynec. Obst. **36**:542, 1923.

20. Cannon; Fraser and Hooper: Some Alterations in the Distribution and Character of the Blood. Report of Shock Committee, Medical Research Committee, no. 25, p. 84, December, 1917.

paper indicate that the reduction in the blood pressure following traumatism to an extremity can be accounted for entirely by the local loss of blood and fluid from the blood stream. In the several experiments in which determinations were made, the reduction in pressure was associated with an increase in both the number of red blood cells and the percentage of hemoglobin. Hence, there may be two types of hemorrhage, that outside the body associated with a dilution of the blood and that into the tissues of the body associated with a concentration. It is well known that the dilution of the blood which occurs after hemorrhage in moderate amounts outside the body is due to the replacement of part or all of the blood volume by the passage of fluid from the tissues into the blood stream. Determination of the percentage of the hemoglobin of the bloody fluid which was found in pools in the injured muscular tissue showed its value to be definitely lower than that of blood obtained from one of the large vessels elsewhere in the body. This probably means that there is a greater proportionate loss of plasma than of red cells after trauma to an extremity. Efforts were made at the completion of some of the experiments to obtain all of the blood from both the traumatized and the nontraumatized extremities. This was impossible. Hence, an accurate determination could not be gained from the results of the experiments of group 1 as to how much of the difference in weight of the two extremities was due to loss of whole blood and as to how much was due to loss of plasma. The fact that the difference in weight of the two sides indicated the loss of fluid from the blood stream which amounted to more than 4 per cent of the body weight in all experiments does not indicate that there is general capillary dilatation elsewhere in the body with pooling of blood. The intestines were examined in many experiments, and no congestion was apparent. There was no free fluid in the peritoneal cavity. The surprisingly small amount of blood which was obtained from the opposite nontraumatized extremity indicated that there was no pooling of blood there. It is believed that these experiments indicate that determinations of the number of red cells and of the amount of hemoglobin do not show whether there has or has not been hemorrhage, but rather whether the hemorrhage is outside the body or into its tissues.

The theory that shock following trauma is due to a toxin was suggested following observations on patients before most of the experimental work was undertaken. Quenu was among the first to stress the possibility that a toxic factor was an important one. A summary of the ideas which had been gained by various men from clinical experience was published by him in 1918.[21] The character of the wounds

21. Quenu: Rev. de chir. **56**:204, 1918.

which were seen most commonly during the war was described by Wallace and Fraser [22] as follows:

> The tissues of the wound are crushed and lacerated, and there are widespread contusion and effusion of blood into the surrounding parts. The neighboring blood vessels are often pulped and thrombosed, and as a result of the interference with the blood supply, whole areas of tissue may afterward die and slough away. In these wounds, muscle appears to be affected more than any other tissue: it becomes a mass of dark brown crushed matter without any evidence of striation or vitality. One cannot fail to be impressed by the enormous destruction which even a small fragment of shell will produce, a degree of destruction which is apparently quite out of keeping with size of the fragment; the exaggerated damage depends upon the enormous velocity at which the fragments are traveling.

McNee, Sladden and McCartney [23] commented on the frequency with which extensive injury of muscle tissue was present in the severe and fatal cases. They reported six cases, in all of which there were extensive lacerations of muscles without injury to bones or to any vital structure or organ. All ended fatally with the exception of one case. Because of the fact that most of the experimental evidence for the presence of a toxemia following injury to muscles was derived from the experiments of Cannon and Bayliss,[11] it seems justifiable to quote their observations and comments on clinical cases at length. They stated:

> The nature of the wounds typically seen in cases of wound shock may be judged from the following records made by one of us at a casualty clearing station where only the most severely wounded men were admitted. Some of them were seen by both of us. In reading these records, it should be understood that the wounds were often made by large, jagged pieces of shell moving at high velocity. When such a missile breaks the humerus or the femur, or the ilium, it smashes and tears extensively the overlying muscles, which, in the thigh and hip, form a thick layer. In all the cases there was shock, accompanied by acidosis.

In all, twelve cases were reported by Cannon and Bayliss. Their description of the injuries is as follows:

> E. G. Compound fracture of left ulna and radius, arm nearly severed; wounds of right arm and left side; abdomen opened, intestine and omentum protruding.
>
> C. P. H. Shell wounds of right thigh, with fracture of the femur, and of left arm with fracture of the humerus; wounds of the face.
>
> G. D. Wounds of the left arm with fracture, left leg with fracture; flesh wounds of the right thigh and abdomen.
>
> G. J. H. H. Shell wounds of right ankle, of left leg with fracture, and of the muscles of the buttock.

22. Wallace and Fraser: Surgery at a Casualty Clearing Station, London, 1918, p. 31; quoted by Cannon.

23. McNee; Sladden, and McCartney: Observations on Wound Shock Especially with Regard to Damage of Muscle. Report of Shock Committee, Medical Research Committee, no. 26, pp. 33-36, March, 1919.

H. J. H. Bursting shell broke right femur, left tibia and fibula, and injured right arm.

A. J. R. Extensive wounds of both legs, left foot and left arm.

W. G. Wounds of buttock with fracture of ilium; also wounds of right foot.

P. K. Fracture of left femur (much comminuted) and right tibia.

W. A. T. Wounds of buttock and perineum; muscles below the buttock torn across and smashed in both legs.

G. K. Wounds of both arms, left thigh, left foot; compound fracture of the right thigh.

R. C. Compond fracture of right femur; multiple shell wounds of left femur, buttock and chest.

A. H. Multiple shell wounds; large wound of left loin involving the gluteal muscles; fracture of pelvis; extensive wounds of right calf muscles and the muscles of the left thigh and left calf, and numerous wounds in back and chest.

The comment of Cannon and Bayliss on these cases of injury is as follows:

It is obvious that with such wounds as these large amounts of muscle would be torn and smashed. And, just as in the animal experiments recorded above, the injured muscle would produce metabolites, which, on being absorbed into the blood stream, would indicate their presence by a decrease in blood pressure, with other signs of shock.

One cannot help but be impressed by the multiplicity and the severity of the wounds in these cases reported by Cannon and Bayliss. Perhaps it is true that the injured muscle would produce metabolites which would lower the blood pressure. It is almost certainly true that the amount of hemorrhage which is necessarily associated with such gross injuries would cause some reduction in the blood pressure.

In the great majority of the reports of injured soldiers in which a low blood pressure and other signs of shock were produced, lesions are described, the nature and extent of which were similar to those described by Cannon and Bayliss. However, usually each series of cases includes one or two instances in which death resulted after varying intervals of time and in which no hemorrhage into the tissues was found. It might be added also that in these cases there were no large masses of lacerated muscle. A report of two such patients was made by Wallace[24] as follows:

One was buried by the explosion of a shell in a cellar, the other was blown up by a buried shell over which he had lighted a fire. Both exhibited all the classic symptoms of shock, which lasted over forty-eight hours; in both treatment was of no avail. In neither did the postmortem examination show any gross lesion.

24. Wallace: Report of Shock Committee, Medical Research Committee, no. 26, p. 7, March, 1919.

There was a great deal of hemorrhage in most of the cases observed by Keith.[25] He described one exception as follows:

> Even without hemorrhage shock may be accompanied by a fall of blood volume. This fact was well brought out in a soldier suffering from very severe symptoms of wound shock, who later died. In this case some 24 hours after 600 cc. of gum acacia solution had been injected intravenously, the hemoglobin amounted to 125 per cent. At autopsy no definite external wounds were found except a few superficial bruises, and no gross internal hemorrhage had occurred. In this case the blood volume was not directly determined, but the high hemoglobin percentage, particularly after the injection of the gum solution, indicated a reduction of the blood volume of at least 25 per cent.

It is interesting that Keith mentioned in the same report the fact that in some instances of failure following the use of gum acacia the gum solution itself had been faulty. It is believed that the condition of the patient at the time the wound is received has a great bearing on the manner in which the injury is tolerated. Cowell[26] stated: "In battle and at points of activity, the conditions of excitement, cold, thirst, fatigue, and possible loss of sleep become important pre-wound factors in initiation of shock." Wallace[24] called attention to the fact that "the soldier was, even in trench warfare, on a limited supply of water, and consequently there was no reservoir on which the circulation could draw in case of need. His condition in this respect much resembled that of a patient after the old fashioned preparation for operation." The effects of an inadequate supply were summarized by Robertson and Bock[27] as follows: "Blood volume tests made on a number of cases of hemorrhage have shown that in many instances dilution of the blood occurs very slowly. The principal reason for this lack of prompt dilution seems to be an initial marked diminution in the reserve fluid of the tissues and the lack of any subsequent attempt to make up the fluid deficiency." It is believed these observations indicate that the death of a person who is subjected to these unfavorable circumstances may occur when the amount of hemorrhage has been relatively small. No work which has been performed to date explains the death of soldiers in which there was no hemorrhage and no gross muscle injury. As has been stated previously, these instances are the exceptional ones. It should be remembered in considering the cases which were observed during the war, that the studies which were made before and subsequent

25. Keith: Blood Volume in Shock, Report of Shock Committee, Medical Research Committee, no. 26, pp. 36-44, March, 1919.

26. Cowell: The Initiation of Wound Shock. Report of Shock Committee, Medical Research Committee, no. 25, p. 108, December, 1917.

27. Robertson and Bock: Memorandum on Blood Volume After Hemorrhage. Report of Shock Committee, Medical Research Committee, no. 25, p. 241, August, 1918.

to the death of the patients were performed under abnormal conditions. Occasional deaths are unexplained in well regulated hospitals when more favorable circumstances for complete studies prevail. Undetected intracranial injuries or gas poisoning might have been the cause for some of the deaths in cases in which the etiology was not determined.

In civil practice, the conditions which attend the development of shock are usually less complicated than are those which were encountered during the war. Cold, fatigue, inadequate fluid and food supplies are usually absent. Many of the patients who are seen in a state of shock in civil practice have had an operation under an anesthetic. In some of these it is doubtful if there has been enough loss of fluid from the blood stream to account for the low blood pressure. Dale [28] showed in experiments on animals that less histamine is required to produce a low blood pressure if the animal is under an ether anesthetic or if hemorrhage has been produced. However, proof that the fall in blood pressure after injury to muscles is due to the formation of histamine is lacking. Previous studies by Blalock [29] and by Blalock and Bradburn [30] showed that the mechanism of the production of a low blood pressure is different after hemorrhage alone and after trauma to the central nervous system. It is believed from a consideration of these observations that all instances of a low blood pressure are not caused by the loss from the blood vessels of whole blood and plasma. The evidence presented in this paper indicates that the loss of fluid or of blood from the blood vessels or the accumulation of blood in dilated vessels occurs exclusively or almost exclusively in the area which has been traumatized. More concretely, the present experiments indicate that trauma to an extremity causes enough loss of blood volume locally to account for the reduction in the blood pressure and it is believed that the accumulation of blood and loss of fluid from the blood stream after intestinal trauma, for example, is limited almost entirely to the area which has been traumatized. The injection of histamine into the patent femoral artery of any extremity in which all of the venous return had been occluded, produced no greater alteration in the blood pressure than simple occlusion of the venous return. This indicates that the important factor in the production of hemorrhage when a tourniquet is placed on tightly enough to occlude the venous return, but not tightly enough to occlude the arterial inflow, is the head of arterial pressure and not the local formation of toxic products.

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28. Dale: Supplementary Note on Histamine Shock. Report of Shock Committee, Medical Research Committee, no. 26, pp. 15-18, March, 1919.

29. Blalock: Mechanism and Treatment of Experimental Shock: I. Shock Following Hemorrhage, Arch. Surg. **15**:762 (Nov.) 1927.

30. Blalock and Bradburn: Trauma to the Central Nervous System: Its Effects on Cardiac Output and Blood Pressure, An Experimental Study, Arch. Surg. **19**:725 (Oct.) 1929.

References have already been made in this discussion to the theories which maintain that nerve impulses or toxic products resulting from trauma initiate the decline in blood pressure. The theory of fat embolism was not supported either in these experiments or in those of Cannon.[31] Examination of the lungs in some of Cannon's experiments showed no accumulation of fat. The femur was not broken in most of the experiments reported here. This is not essential, however, as Lehman and Moore [32] showed that it is not necessary to fracture long bones or indeed to produce gross trauma of any kind in order to produce fat embolism. The fact that the local loss of blood volume accounted for the decline of pressure in the present experiments, shows that fat embolism, if present, was not the cause of the condition found.

The respirations were observed carefully in many of the experiments, and there was nothing to indicate that the shock was due to overventilation. The respirations were slow most of the time, and when they became slightly accelerated the amplitude decreased. The theory of acapnia found no support in the experiments of Cannon,[31] in which he found that shock could be produced by muscle injury even though the breathing was kept uniform by artificial means.

It has been shown [33] that shock is not produced by acidosis alone by the injection of acid into the blood stream until the alkali reserve was reduced to a low degree. The blood pressure did not fall to a shock level. Bayliss [17] found that the injection of lactic acid, after a low blood pressure had been produced by muscle injury, did not exaggerate the state and in some instances caused an elevation of the blood pressure. Conflicting results have been obtained by different observers [34] in studies of the epinephrine content of the blood when the blood pressure is at a low level. To produce a low blood pressure, it is necessary to inject a much larger amount of epinephrine than is liberated by reflex stimulation.[35] The experiments of Mann [36] in which he found that the suprarenal glands can be removed without producing shock are evidence against the theory of suprarenal exhaustion. In regard to the part which infection may play in the development of shock, Cannon [37] stated, "Furthermore, the state is commonly well established before infection, and therefore is not of bacterial origin." McNee, Sladden and McCart-

31. Cannon (footnote 3, p. 147).

32. Lehman and Moore: Fat Embolism Including Experimental Production Without Trauma, Arch. Surg. **14**:620, 1927.

33. Acidosis and Shock. Report of Shock Committee, Medical Research Committee, no. 25, p. 257, October, 1918.

34. Bedford and Jackson: Proc. Soc. Exper. Biol. & Med. **13**:36, 1916. Stewart and Rogoff: Am. J. Physiol. **48**:22, 1919.

35. Cannon (footnote 3, p. 125).

36. Mann: Shock During Anesthesia, J. A. M. A. **69**:373 (Aug. 4) 1917.

37. Cannon (footnote 3, p. 154).

ney [23] made studies on many wounds obtained during the war from the point of view of infection. They stated, "Bacterial infection, moreover, was shown to be unimportant in these wounds." No evidence to support any of these theories was found in the present experiments, since it was found that the local loss of blood volume was sufficient to account for the reduction in the blood pressure.

A great deal of work has been performed to determine the effects on the blood pressure of the injection of extracts of various tissues, of the products of autolysis of crushed muscle and of many other substances. Most of these substances caused a decline in the blood pressure. No evidence for the action of any of these products was found in the present experiments. Many of the substances which were studied are supposed to be fairly closely related to histamine. Goodpasture [38] found that a fresh extract of the pancreas produced changes in the gallbladder similar to those observed by Bradburn and Blalock [14] after the injection of histamine. Trauma to the extremities did not produce any alteration in the gallbladder.

It is believed that one should be guarded in drawing conclusions which apply to man from experimentation on animals, particularly if the latter have been anesthetized. Barbital, the anesthetic which was used in these experiments, does not lessen greatly the amount of the loss of blood which is necessary for the production of a low blood pressure. Dale [28] found that a cat which had been anesthetized by ether for two hours would tolerate only one-fifth as much histamine without the production of death as would the same cat without an anesthetic. Concerning the effect of trauma to the anesthetized animal, he stated, "It seems in the highest degree probable that the sensitiveness of the animals to traumatic toxins has been thereby greatly enhanced." The effect of barbital anesthesia on the tolerance to histamine has not been determined. Ether anesthesia causes little alteration in the amount of hemorrhage that is necessary for the production of a low blood pressure. If the results of these experiments had indicated that the decline in pressure following trauma to an extremity is due to a toxin, they would be received in a more skeptical light in view of Dale's work, which showed that anesthesia increases the susceptibility to histamine. Since the decline in pressure in the present experiments was due to the loss of a large part of the blood volume into the traumatized area, it is believed that similar results would be obtained on unanesthetized animals. Shock in the human being is usually associated with the loss of a great deal of fluid through sweating. This is not encountered in dogs because of the absence of sweat glands. It is fortunate in experiments of this type that such is the condition, because a more accurate idea can be gained as to the site of the loss of fluid from the blood stream.

38. Goodpasture: J. Exper. Med. **25**:277, 1917.

SUMMARY

All the experiments were performed on dogs, anesthetized by barbital. The blood pressure was determined frequently. The experiments were undertaken in order to test the various theories which have been advanced in an effort to explain the initiating agent in the development of a low blood pressure after gross trauma. In some experiments, the method of Cannon and Bayliss, by which they produced a decline in blood pressure by traumatizing a posterior extremity, was employed. In other experiments, their procedure was altered in various ways.

The following is a brief summary of the results:

1. The blood pressure could not be reduced to a shock level by trauma to one of the posterior extremities without causing the loss of a sufficient part of the blood volume into the traumatized area to account for the decline in the pressure. There was a greater proportionate loss of plasma than of red cells, and this accounts for the concentration of the blood elsewhere.

2. The injection of histamine into the patent femoral artery of a thigh which was tightly constricted by a tourniquet, in some instances, caused a fall in blood pressure. After the uppermost part of the femur had been removed, the injection of histamine into the artery did not cause a decline in pressure if the tourniquet was properly applied.

3. After the femoral artery had been freed in the groin and a tourniquet had been placed around the thigh constricting everything except the artery, no appreciable decline in pressure resulted whether the femur was or was not resected. The injection of histamine into the artery caused no greater alteration in the pressure than did the simple application of the tourniquet. The application of tourniquets to both thighs by the same method caused a marked fall in the blood pressure.

4. A fall in blood pressure to a low level was produced by trauma to an extremity, the thigh of which was constricted by a tourniquet, except for the femoral artery. A sufficient amount of hemorrhage occurred into the traumatized part to account for the decline in the blood pressure. This occurred whether the upper part of the femur had or had not been removed.

5. Removal of the tourniquet from a thigh, the structures of which had been constricted for a long time, except for the femoral artery, caused a fall in the blood pressure. The same result was obtained whether there had or had not been trauma.

6. After the femoral artery and vein had been dissected free in the groin and a clip had been placed on the vein and a tourniquet which constricted all of the structures of the thigh, except the artery and vein, had been placed beneath the vessels, removal of the clip from the

vein usually did not cause a decline in the blood pressure. The same result was obtained whether there had or had not been trauma and whether the upper part of the femur had or had not been removed.

7. When the arterial inflow and the venous outflow to an extremity were entirely occluded, gross trauma to the extremity did not produce a decline in the blood pressure.

8. Massage of either the traumatized or the opposite nontraumatized extremity usually produced a temporary reduction in the blood pressure.

9. After the blood pressure had been lowered by trauma to an extremity, occlusion of the terminal aorta and vena cava was followed by a fall or a rise or no alteration in the blood pressure.

10. If the terminal abdominal aorta or vena cava of the dog had been occluded for an hour, release of the occlusion did not result in the production of a low blood pressure.

11. The transfusion of blood from one dog in which a low blood pressure has been produced by trauma to an extremity to another dog in which a low blood pressure had been produced by a loss of blood either outside the body or into the tissues of the body resulted in an elevation of the blood pressure in the recipient.

12. The intravenous injection of histamine caused definite alteration in the gallbladder. Trauma to any extremity did not produce these changes.

13. Trauma to an extremity did not cause a congestion of blood in the intestinal tract or the accumulation of free fluid in the peritoneal cavity.

The experiments which are presented in this paper offer no evidence that trauma to an extremity produces a toxin that causes a general dilatation of capillaries with an increase in capillary permeability and a general loss of fluid from the blood stream. Neither do they lend support to the other theories, such as fat embolism, acidosis, acapnia, suprarenal hyperactivity and hypoactivity and vasomotor exhaustion. There was a sufficient loss of blood volume into the traumatized area in all these experiments on dogs anesthetized by barbital to account for the reduction in the blood pressure. The time interval which elapsed between the initiation of the trauma and the reduction of the blood pressure to a shock level probably was not sufficiently great in these experiments to rule out the effects of decomposition products which are very slow in their actions. However, these experiments are comparable in the time required for the production of a low blood pressure with those of the other investigators whose theories have been discussed. It has been pointed out that definite conclusions cannot be drawn from these experiments as to the mechanism of the production of shock in man.

BILIARY AND HEPATIC FACTORS IN PEPTIC ULCERS

AN EXPERIMENTAL STUDY *

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Numerous investigators [1] observed the occurrence of peptic ulcers in animals following the diversion of duodenal secretions, and attributed the development of these lesions to the loss of the neutralizing influence of the alkaline duodenal fluids on the acid gastric juice. Their conclusions were based on the work of Boldyreff,[2] who promulgated the theory that gastric acidity was regulated by the regurgitation of the contents of the duodenum into the stomach. Boldyreff noted that the pancreatic juice was more alkaline than any of the other secretions that were present in the duodenum, and he believed that it was the chief factor in the neutralization of the acid secreted by the stomach. The results of the investigations of MacLean and Griffiths,[3] McCann,[4] and Yesko,[5] however, indicated that changes in gastric acidity did not depend on the regurgitation of alkaline duodenal juices. Recent determinations [6] of the gastric acidity in animals with pancreatic or bile fistulas showed that

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the acid values remained within the limits of normal variations for dogs; after biliary obstruction, the acidity was increased.[7]

If Boldyreff's theory were correct, there would be a greater predisposition to the formation of peptic ulcers in animals which were deprived of their pancreatic juice than in those which were deprived of their bile. A survey of the literature revealed that ulcers were rarely reported after ligation of the pancreatic ducts or extirpation of the pancreas [8] but were observed frequently after biliary exclusion.[9] The following study deals with the experimental production of duodenal and gastric ulcers in dogs by interference with the flow of bile into the intestine and the possible significance of the results with respect to peptic ulcers in man.

METHODS

Under ether anesthesia and with aseptic precautions, biliary fistulas were established in a series of large dogs according to the method described by Rous and McMaster.[10] The common duct was ligated and divided near the intestine. A cannula attached to a rubber U-tube was inserted into the proximal end of the divided duct. The tube was brought out through the abdominal wall by means of a stab wound just below the costal margin. The free end of the drainage tube was then connected to a small glass T, to which a rubber collecting bag and a rubber outlet tube were attached. The whole apparatus was held in place by a protective dressing. This method permitted the collection of the total output of bile under sterile conditions and insured against the animals licking the fistulous openings. Accessory communications between the biliary tract and the intestine were ruled out at autopsy. The gallbladder was dealt with as follows: In some animals it was allowed to remain intact; in others the cystic duct was ligated and divided; in a number of dogs a cholecystectomy was performed; in one animal a cholecystostomy was done after ligation and division of the common duct.

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Twenty-three dogs were studied, and they were divided into three main groups. In group 1, the flow of bile from the fistula remained uninterrupted throughout the experiment. In group 2, at first, the drainage of bile was free after the establishment of the fistula. Subsequently, however, obstruction developed and the flow of bile became intermittent or ceased. In group 3, the operation for fistula was unsuccessful from the beginning, and complete biliary obstruction followed.

After prolonged drainage the bile usually became contaminated, but this did not seem to alter the secretion to any extent. All of the animals were kept on a diet low in fat. For control study, a series of fifty normal dogs was examined, and no spontaneous ulcers of the duodenum or of the stomach were encountered. As another control study, nine dogs with pancreatic fistulas were observed over the following periods: seventeen, twenty, twenty-two, twenty-two, twenty-two, twenty-five, thirty, fifty-one and fifty-two days, respectively, and no lesions were found in the stomach or the duodenum.

EXPERIMENTAL OBSERVATIONS

Series 1, Dog 509.—In a male mongrel, weighing 15 Kg., a bile fistula was produced, with cholecystectomy. Secretion continued throughout the experiment. The animal became extremely weak and emaciated and was found dead on the sixteenth day.

Autopsy.—The dog weighed 12.1 Kg. A round, penetrating, acute ulcer was found on the anterior surface of the duodenum opposite the ampulla of Vater.

Dog 510.—In a dog, weighing 26 Kg., a bile fistula was produced, with cholecystectomy. The animal secreted large amounts of bile throughout the experiment. It began to vomit on the twelfth day, and was found dead on the fourteenth day.

Autopsy.—The dog weighed 19.7 Kg. A few pockets of pus were found between the lobes of the liver, which was normal otherwise. On the anterior surface of the doudenum just below the pylorus, there was an acute, oval, penetrating ulcer measuring 2.5 by 1.5 cm., with irregular, undermined margins.

Microscopic Examination.—Examination revealed an acute, penetrating ulcer, which involved all the layers of the duodenum down to the serosa. The margins were undermined. The surface of the ulcer was covered by an amorphous material. There was no cellular reaction.

The liver was normal, except for marked congestion of the capillaries in the central portions of the lobules. The pancreas and lungs also showed marked congestion of the blood vessels.

Dog 511.—In a female mongrel, weighing 17.1 Kg., a bile fistula was produced, with cholecystectomy. Secretion continued throughout the experiment. The animal became progressively weaker and was found dead on the thirteenth day.

Autopsy.—The dog weighed 13.2 Kg. Diffuse suppurative peritonitis was present. A punched out, perforated ulcer measuring 1.5 by 0.7 cm. was found on the anterior surface of the duodenum 1.5 cm. below the pylorus. The perforation was sealed over incompletely by omentum. The liver was normal, except

for a fibrinopurulent exudate which covered the surface. The lungs showed consolidation of the right lower lobe. The spleen was small and contracted.

Microscopic Examination.—There was an acute perforated ulcer extending through all the coats of the duodenum. The margins were sharply defined, and in the underlying tissues there was a moderate infiltration of polymorphonuclear leukocytes. Adjacent to the perforation, the base was formed by a thin layer of muscle and the fibrous wall of the biliary sinus tract. The surface of the ulcer was covered by cellular débris and polymorphonuclear leukocytes. The surface of the liver was covered by a fibrinopurulent exudate. The capillaries

Fig. 1.—Acute perforated duodenal ulcer in dog 511.

in the central portions of the liver lobules were dilated, and the cords were compressed. The lungs showed lobar pneumonia.

Dog 13-28.—In a male collie, weighing 18.8 Kg., a bile fistula was established, with the gallbladder intact. Secretion continued throughout the experiment. The animal became progressively weak and was killed on the twelfth day because of its poor condition.

Autopsy.—The dog weighed 17.7 Kg. The wound was infected. In the duodenum there were two acute shallow ulcers, opposite one another. They were about 3 cm. below the pylorus, the one on the anterior surface measuring 1.5 by 0.5 cm. and the one on the posterior surface, 1 by 0.5 cm. The bases were

covered by a green slough. The mucosa of the duodenum was congested as far down as the main pancreatic orifice.

Microscopic Examination.—Both ulcers were typical acute mucosal erosions of the duodenum extending down to the muscularis mucosae with polymorphonuclear and round cell infiltration of the underlying tissues.

Dog 21-28.—In a female mongrel, weighing 14.4 Kg., a bile fistula was produced, with the gallbladder intact. The average daily output of bile was 78 cc. Secretion continued for fifty-three days, then ceased. The animal was killed on the fifty-fifth day. No icterus was observed.

Autopsy.—The dog weighed 10.4 Kg. No ulcers were found. The liver appeared normal. The gallbladder was of about normal size and was filled with ropy, golden yellow bile. The bile ducts were moderately dilated. The glass

Fig. 2 (dog 511).—Biliary fistula, thirteen days. Acute perforated duodenal ulcer. Reduced from × 18.

U-tube was filled with thick, muddy, inspissated bile which probably interfered with the outflow of bile.

Microscopic Examination.—The liver showed marked central fatty degeneration, pericholangitis and pericholangitic abscesses.

Dog 10-29.—In a female airedale, weighing 14.4 Kg., a biliary fistula was established, with cholecystectomy. The average daily output of bile was 64 cc. Bile was secreted during the entire period of experiment, and the dog remained in excellent condition. It was killed on the fifty-second day.

Autopsy.—The dog weighed 13.1 Kg. No gross abnormalities were observed. No ulcers were found. Microscopic examination was not made because of autolysis of the viscera.

Dog 22-29.—In a male mongrel, weighing 15.5 Kg., a biliary fistula was produced, with cholecystectomy. The average daily output of bile was 142.5 cc.

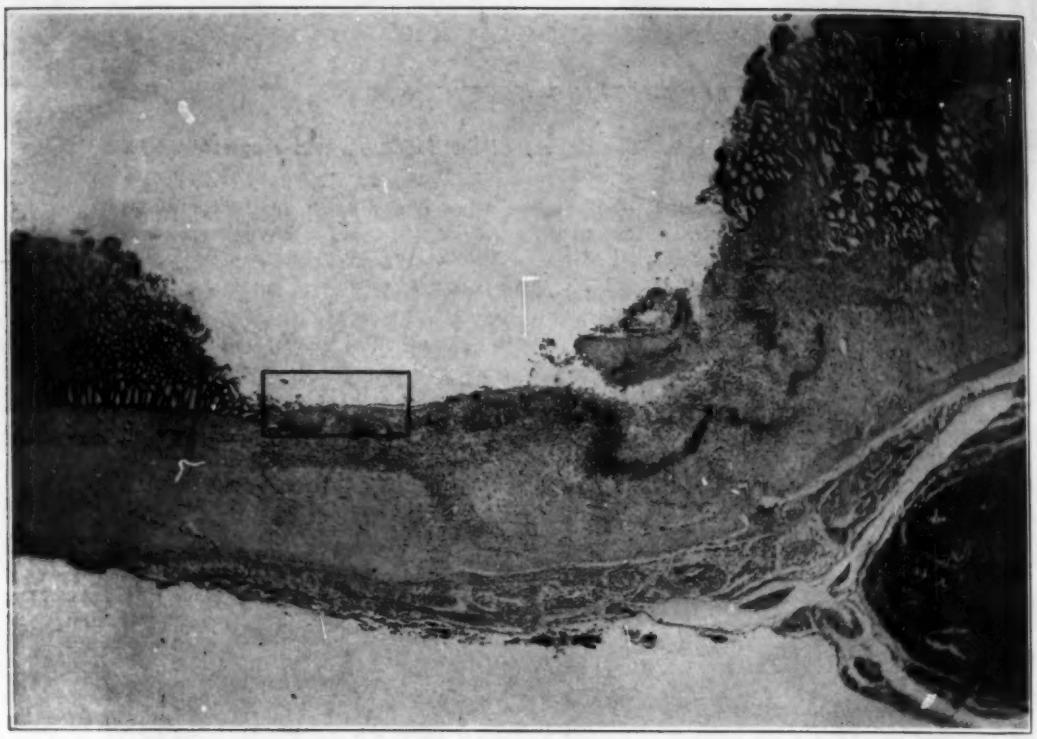

Fig. 3 (dog 505).—Biliary fistula followed by biliary obstruction, twenty-nine days. Chronic penetrating duodenal ulcer with evidence of healing. Reduced from × 21. See figure 4.

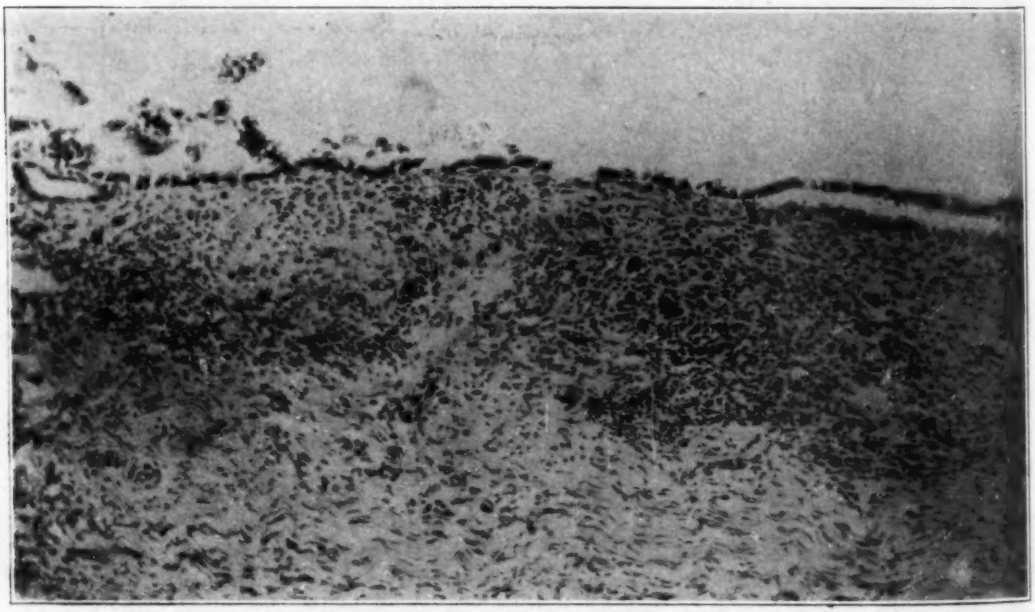

Fig. 4 (dog 505).—Area included in square in figure 3. High power magnification shows the base of the ulcer filled in by newly formed connective tissue covered by regenerating epithelium. Reduced from × 180.

Bile was secreted throughout the experiment, and the dog remained in excellent condition. It was killed on the one hundred and second day.

Autopsy.—The dog weighed 13.3 Kg. The liver appeared normal. There was no dilatation of the bile ducts, and the cannula was in situ. There were no ulcers of the stomach or duodenum. Numerous pinpoint cortical abscesses were found in the kidneys.

Microscopic Examination.—Microscopic examination revealed no abnormalities of the viscera, except the kidneys, which showed an occasional cortical abscess.

Series 2, Dog 505.—In a male collie, weighing 18.2 Kg., a bile fistula was produced, with ligation and division of the cystic duct. There was intermittent drainage. Bile was secreted for one week; the secretion then stopped for four days, started again for one week, stopped for one day and then continued until death, which occurred suddenly on the twenty-ninth day.

Autopsy.—The dog weighed 13.7 Kg. Suppurative peritonitis was present. On the anterior surface of the duodenum just below the pylorus, there was an

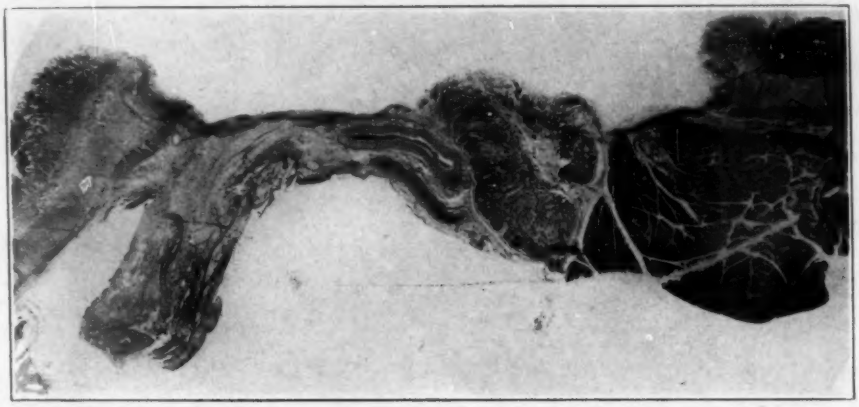

Fig. 5 (dog 506).—Cholecystostomy with intermittent drainage, fifty-six days. Large chronic perforated duodenal ulcer. Base formed by adherent omentum, pancreas and lymph node. Reduced from × 6.

oval, indurated, penetrating ulcer measuring 1 by 0.5 cm. The liver was firm and icteric. The spleen was small and firm. The mesenteric lymph nodes were enlarged and soft. The pancreas was firm.

Microscopic Examination.—There was a chronic penetrating ulcer, with evidence of healing. The ulcer extended partly through the outer longitudinal muscular layer. The margins were sharply defined. The base showed a marked proliferation of connective tissue and infiltration with leukocytes. The surface of the ulcer was covered by regenerating epithelium. In the liver, the bile canaliculi were dilated in the central portions of the lobules. Many of the Kupffer cells contained bile pigment. There were a few focal necroses and a moderate periportal infiltration with mononuclear leukocytes.

Dog 506.—In a male mongrel, cholecystostomy was performed, with ligation and division of the common duct. Drainage was intermittent due to contraction of the orifice of the fistula. During such periods "white bile" was secreted. The animal became progressively weak and emaciated and died after fifty-six days.

Autopsy.—The fistulous tract was patent. The mucosa of the gallbladder was normal. The common and hepatic ducts were dilated. The liver showed no gross changes. On the anterior surface of the duodenum, about 4 cm. below the pylorus, there was an irregular indurated ulcer 2.3 cm. in diameter, which had perforated, but the perforation was sealed over by adherent omentum and pancreas.

Microscopic Examination.—A chronic ulcer was present, which involved all the layers of the duodenum. Beneath the abrupt margins, connective tissue proliferation and infiltration with polymorphonuclear leukocytes and round cells were found. The base of the ulcer was formed by adherent omentum,

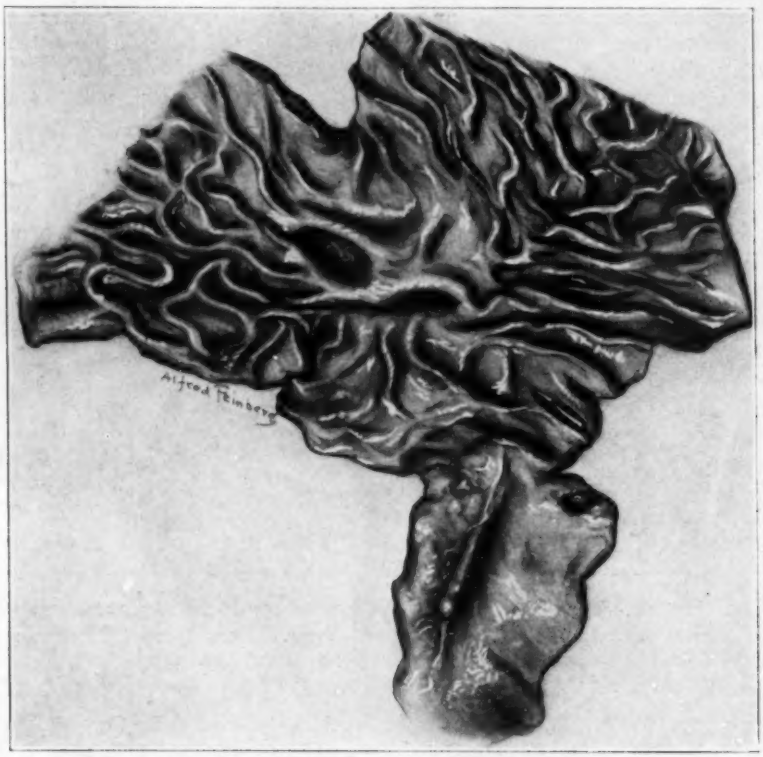

Fig. 6.—Subacute duodenal and gastric ulcers in dog 507.

pancreas and a lymph node; overlying these there was a layer of granulation tissue and leukocytes.

The liver showed dilated bile canaliculi and degeneration of the liver cells in the central areas of the lobules. The larger bile ducts were dilated.

Dog 507.—In a male mongrel, weighing 20.8 Kg., a bile fistula was established, with ligation and division of the cystic duct. Secretion continued for twenty-six days, then diminished and finally ceased. The animal became progressively jaundiced and emaciated and was killed on the forty-sixth day.

Autopsy.—The dog weighed 12 Kg. Three ulcers were found, two gastric and one duodenal. The duodenal ulcer was punched out and measured 0.5 by 0.3 cm. It was on the anterior surface just below the pylorus. The gastric ulcers occurred

on the lesser curvature, 4.5 and 5.5 cm., respectively, above the pylorus. Both were penetrating ulcers with undermined margins and one of them had perforated, the perforation being sealed over by omentum. They measured 1.7 by 1 cm. and 1.7 by 0.5 cm., respectively. The liver was firm and icteric. The larger

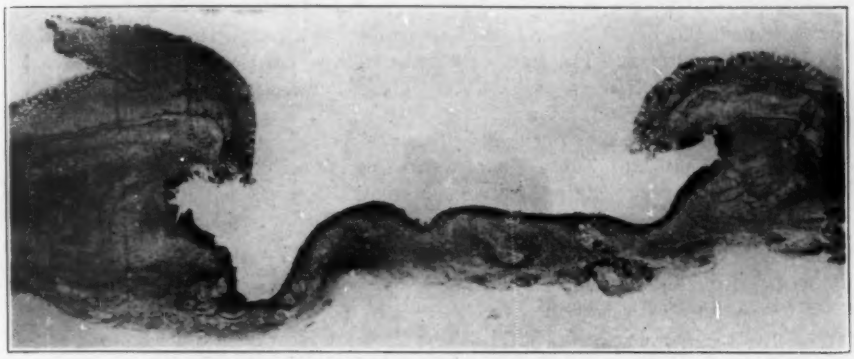

Fig. 7 (dog 507).—Biliary fistula followed by biliary obstruction, forty-six days. Subacute gastric ulcer with overhanging edges. Reduced from × 13½.

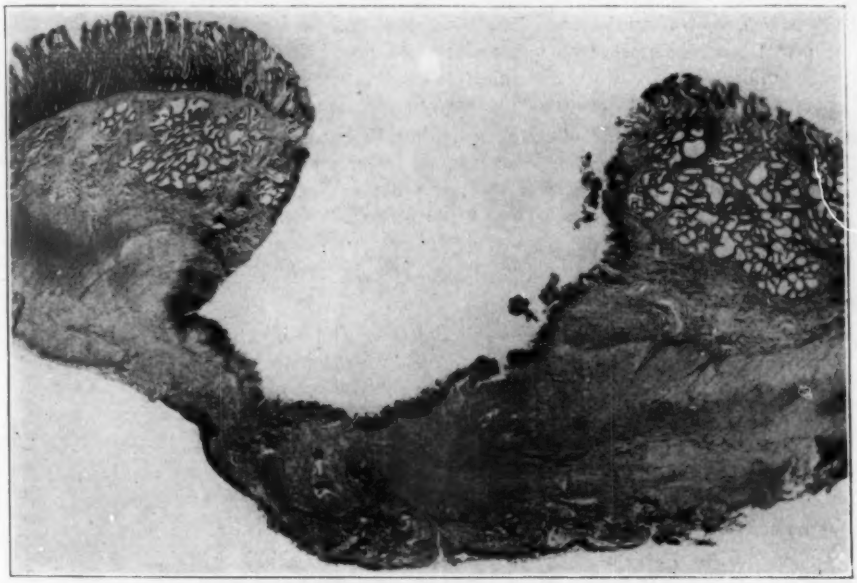

Fig. 8 (dog 507).—Biliary fistula followed by biliary obstruction, forty-six days. Subacute duodenal ulcer. Reduced from × 25.

bile ducts were dilated, and a stricture was found in the common duct just above the cannula. The regional lymph nodes were enlarged and icteric. The right lung was completely consolidated; the left showed patchy consolidation.

Microscopic Examination.—The duodenal ulcer was of the subacute penetrating type with abrupt margins. It extended through all the layers of the

intestine down to the serosa. The surface of the ulcer was covered by a purulent exudate of polymorphonuclear leukocytes and round cells which infiltrated the underlying structures. The base was formed by newly formed connective tissue. The serosa opposite the ulcer was thickened and contained proliferating fibroblasts, capillaries and numerous polymorphonuclear leukocytes. The gastric ulcers had similar histologic characteristics; one had perforated. The margins were undermined, and the base was formed by newly formed connective tissue covered by a cellular exudate. The serosa showed the same reaction as in the duodenal ulcer. In the liver, the larger bile ducts were dilated and the small bile canaliculi were distended near the centers of the lobules. The Kupffer cells in this region contained bile pigment. Pericholangitis, pericholangitic abscesses and focal necroses were present. There was also some periportal fibrosis. The lungs were the seat of a hemorrhagic pneumonia. In the kidneys, there was a hemorrahgic exudate in the glomeruli with numerous thrombi in the capillaries.

Dog 508.—In a male terrier, weighing 19.5 Kg., a bile fistula was established, with ligation and division of the cystic duct. Secretion continued for sixteen days, then ceased. The animal was found dead on the twenty-sixth day.

Autopsy.—The dog weighed 14.1 Kg. Suppurative peritonitis due to a perforated duodenal ulcer was found. A punched out, indurated ulcer, measuring 2 by 1.2 cm., was found on the anterior surface of the duodenum, 1.5 cm. below the pylorus. In the base there was a small perforation. There was autolysis of the other organs.

Microscopic Examination.—The ulcer that had perforated was of the chronic type. Its margins were abrupt, and the base was formed by connective tissue. The underlying tissues were infiltrated by polymorphonuclear leukocytes and round cells. The surface was covered by amorphous material and cellular débris.

Dog 512.—In a male mongrel, weighing 13 Kg., a bile fistula was produced, with cholecystectomy. Secretion continued for nine days, then became intermittent and finally ceased on the twenty-seventh day. The animal was icteric and in good condition when it was killed on the forty-first day.

Autopsy.—The dog weighed 10.3 Kg. The liver was firm and icteric. The bile ducts were dilated. No ulcers were found. Microscopic examination was not made.

Dog 17-28.—In a male airdale, weighing 17.8 Kg., a bile fistula was established, with the gallbladder intact. The average daily secretion of bile was 94 cc. Secretion continued for thirty days, then ceased. The animal became jaundiced and was found dead on the thirty-sixth day, following an exploratory laparotomy.

Autopsy.—The dog weighed 17.2 Kg. There were diffuse suppurative peritonitis and marked autolysis of all the organs. A stricture of the common duct was found just above the cannula. No ulcers were found. No microscopic examination was made because of autolysis of the organs.

Dog 18-28.—In a male collie, weighing 12.5 Kg., a biliary fistula was established, with the gallbladder intact. The average daily output of bile was 62.5 cc. Secretion continued for sixty-five days, then icterus was noted, and the animal was killed on the sixty-seventh day.

Autopsy.—The weight was 9.6 Kg. There was a small, oval erosion of the mucosa of the duodenum 2 cm. below the pylorus. The liver was icteric, and contained numerous small abscesses. The bile ducts and gallbladder were distended with ropy, turbid, dark green bile. The glass cannulas were filled with inspissated dark brown bile which probably interfered with the free outflow of bile and caused a partial obstruction.

Microscopic Examination.—The lesion in the duodenum was a shallow, small, mucosal erosion. The changes were not sufficiently marked to be considered a true ulcer, and the lesion was not included in the results. Dilated bile canaliculi, proliferation of the smaller bile ducts, pericholangitis and pericholangitic abscesses were found in the liver. Numerous focal necroses and a few infarcts were also present. The gallbladder showed no changes.

Dog 2-29.—In a male mongrel, weighing 17 Kg., a bile fistula was established, with the gallbladder intact. The average daily output was 119 cc. After seventy-three days of continuous secretion, an exploratory operation was performed. No ulcer was palpable in the stomach or duodenum. The liver and biliary tract appeared normal. The gallbladder contained a small amount of thick, dark, viscid brown bile. A cholecystectomy was performed at this time. Following the operation, jaundice developed and the secretion of bile stopped. The animal was killed seven days afterward.

Autopsy.—The dog weighed 15.3 Kg. Diffuse suppurative peritonitis was present. On the anterior surface of the duodenum, 1.5 cm. below the pylorus, there was a round, punched out ulcer measuring 1 cm. in diameter. The base was covered with slough. The liver was jaundiced, the bile ducts were dilated and inspissated bile filled the lumen of the U-tube, which probably accounted for the development of the obstruction. There was no stricture of the common duct.

Microscopic Examination.—There was a duodenal ulcer of the subacute penetrating type, with abrupt margins, involving the inner circular and part of the outer longitudinal coats. The surface was covered by a purulent exudate. In the base there was newly formed connective tissue. The underlying tissues were infiltrated by polymorphonuclear leukocytes. Overlying the ulcer, the serosa was thickened and contained proliferating capillaries and young fibroblasts. The bile canaliculi of the liver were distended, especially in the central portions of the liver lobules. The Kupffer cells contained bile pigment. No other changes were observed.

Dog 3-29.—In a male collie, weighing 16.9 Kg., a bile fistula was produced, with the gallbladder intact. The average daily secretion of bile was 114.5 cc. Secretion continued for thirty-six days, then ceased. The animal became jaundiced and was killed on the forty-first day.

Autopsy.—The dog weighed 13.4 Kg. The liver was firm. The gallbladder and bile ducts were dilated, and a stricture of the common duct was found just above the cannula. No ulcers were found.

Microscopic Examination.—The liver showed dilated bile canaliculi in the central portions of the lobules, pericholangitis and multiple abscesses.

Dog 15-29.—In a male terrier, weighing 14.6 Kg., a bile fistula was established, with cholecystectomy. The average daily secretion of the bile was 123 cc. Secretion continued uninterrupted throughout the experiment until the last few days, when a slight icterus of the conjunctivae was noted. The animal was killed on the sixty-ninth day. The general condition was excellent throughout the experiment.

Autopsy.—The dog weighed 16 Kg. The liver was firm and icteric. The bile ducts were not dilated, the cannula was in place and there was no stricture. The cause for the icterus was not determined; possibly there was a partial obstruction due to inspissation of bile in the lumen of the U-tube. No ulcers were found.

Microscopic Examination.—The liver showed dilatation of the bile canaliculi in the central portions of the lobules, proliferation of the smaller bile ducts and pericholangitis.

Dog 34-29.—In a female mongrel, weighing 17.1 Kg., a bile fistula was produced, with cholecystectomy. The average daily output of bile was 126 cc. Bile was secreted throughout the experiment, with some diminution toward the end. The conjunctivae showed some jaundice at this time. The general condition remained excellent. The animal was killed with ether on the ninety-ninth day.

Autopsy.—The tissues were icteric. The liver was small, firm and jaundiced. The common and hepatic ducts were dilated. Thick turbid bile was found in the ducts. One of the hepatic ducts was completely obstructed by the tube and cannula. In the stomach, on the lesser curvature 4 cm. below the cardia, there was a shallow irregular ulcer with overhanging edges measuring 2 by 0.5 cm. In addition, there were numerous smaller erosions in the fundus and one just above the pylorus. In the duodenum, just below the pylorus on the anterior surface, there was an irregular stellate shallow ulcer 1 by 0.5 cm. On the posterior surface of the duodenum, there was a small erosion about 0.3 cm. in diameter. The lymph nodes at the hilus of the liver were enlarged and icteric.

Microscopic Examination.—The gastric and duodenal lesions were typical mucosal erosions without any cellular reaction. The liver showed distended bile canaliculi in the central portions of the lobules, pericholangitis, periportal fibrosis, proliferation of the smaller bile ducts and focal necroses. The Kupffer cells contained bile pigment. The larger bile ducts were dilated.

Series 3, Dog 7-28.—In a female collie, weighing 13 Kg., a bile fistula was established, with the gallbladder intact. The fistula did not function. The animal became progressively weak and jaundiced and was killed on the thirty-third day because of its poor condition.

Autopsy.—There was marked jaundice. The liver was shrunken, soft and deeply icteric, with numerous small abscesses. The spleen was small and of rubbery consistency. There was old blood in the stomach, but no ulcers were found. The gallbladder and ducts were markedly distended with thick, viscid bile. There was a stricture of the common duct above the cannula.

Microscopic Examination.—The liver showed distended bile canaliculi, proliferation of the smaller bile ducts, pericholangitis and pericholangitic abscesses. The Kupffer cells contained bile pigment.

Dog 12-28.—In a male airedale, weighing 19 Kg., a biliary fistula was produced. with the gallbladder intact. There was a small irregular secretion which ceased completely on the fourteenth day. The animal became progressively jaundiced and was found dead on the fifty-seventh day.

Autopsy.—The animal was thin and jaundiced. The bile ducts and gallbladder were dilated because of a stricture of the common duct above the cannula. The liver was firm and icteric. The heart muscle was flabby. No ulcers were found.

Microscopic Examination.—The liver showed distended bile canaliculi, proliferation of the smaller bile ducts and periportal fibrosis. The capillaries in the central portions of the lobules were dilated, and the liver cords were compressed.

Dog 5-29.—In a female collie, weighing 15.7 Kg., a biliary fistula was established, with cholecystectomy. The fistula did not function. The dog remained in excellent condition throughout the experiment, although jaundice was marked. The animal was killed with ether on the one hundred and eighty-ninth day.

Autopsy.—The dog weighed 14.4 Kg. On the anterior surface of the duodenum, 1 cm. below the pylorus, there was a penetrating, indurated ulcer measuring 1.5 cm. in diameter. The liver was small, firm and icteric. The larger bile ducts were dilated and contained pus. There was a stricture of the common duct just above the cannula. The mesenteric lymph nodes were enlarged.

Microscopic Examination.—There was a chronic duodenal ulcer, with evidence of healing. The ulcer extended through Brunners's glands and the inner circular layer down to the outer longitudinal muscular coat. The surface was covered by a layer of polymorphonuclear leukocytes which infiltrated the underlying tissues. The crater was filled in by connective tissue. Along the edges of the ulcer, there was an outgrowth of new epithelium. The liver showed distended bile canaliculi in the central portions of the lobules, proliferation of the smaller bile ducts and an increase of the periportal connective tissue. The Kupffer cells contained bile pigment. Occasional large abscesses containing numerous pigment-laden phagocytes were also found in the liver.

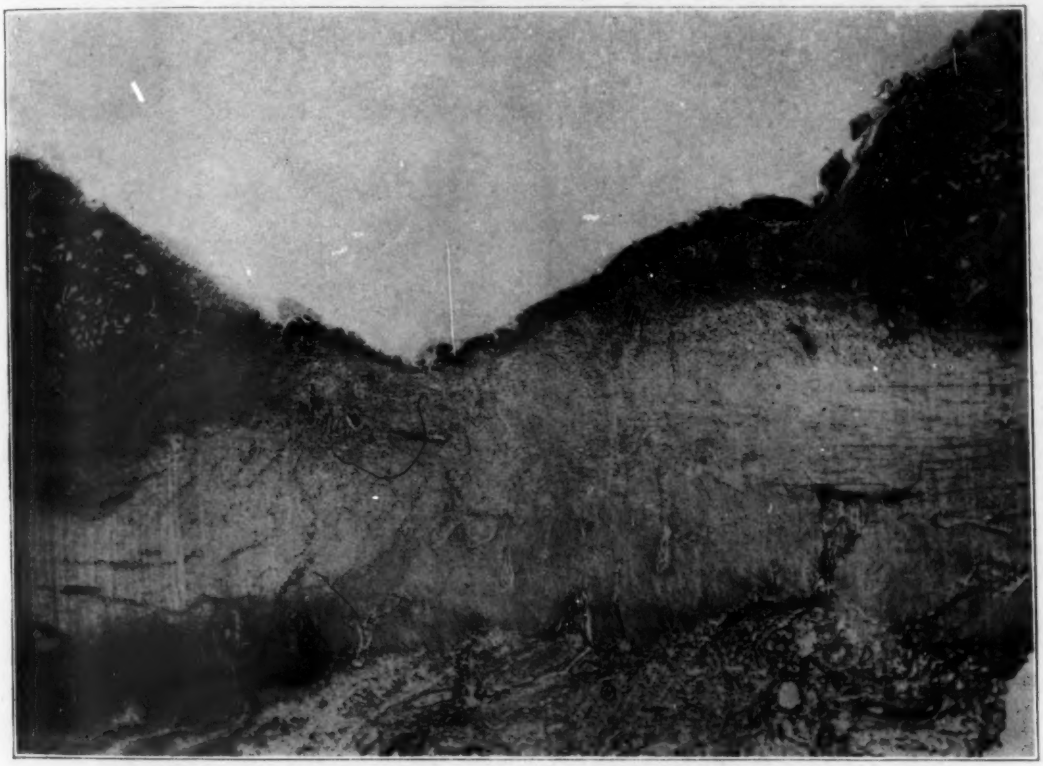

Fig. 9 (dog 5-29).—Biliary obstruction, 189 days. Chronic duodenal ulcer with evidence of healing. The base is filled in by connective tissue. Reduced from × 24.

Dog 11-29.—In a female collie, weighing 16.4 Kg., a biliary fistula was established, with cholecystectomy. The fistula did not function. The dog became progressively emaciated and jaundiced and was found dead on the forty-seventh day.

Autopsy.—Intense jaundice and marked ascites were present. The peritoneal fluid was a turbid yellow. A chronic perforated ulcer with indurated overhanging edges, measuring 2 by 0.5 cm., was found on the anterior surface of the duodenum 2 cm. below the pylorus. Another similar ulcer, measuring 2 by 2.5 cm., was

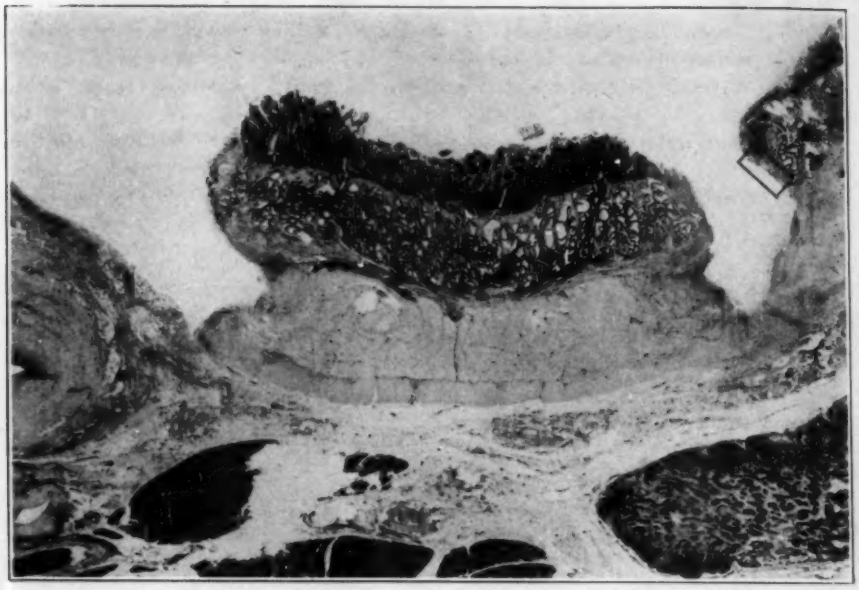

Fig. 10 (dog 11-29).—Biliary obstruction, forty-seven days. Two chronic perforated duodenal ulcers, with evidence of attempted healing in one of them. Reduced from × 12. See figure 11.

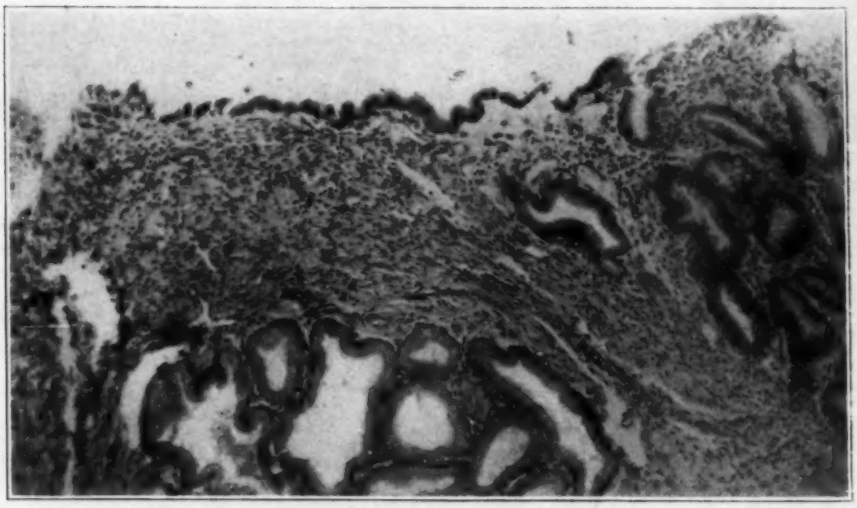

Fig. 11 (dog 11-29).—Area included in square in figure 10. High power magnification shows proliferating fibroblasts covered by regenerating epithelium. Reduced from × 180.

found on the posterior wall of the duodenum in the region of the ampulla of Vater, and adherent to the pancreas. In the antrum of the stomach there were multiple mucosal erosions. The liver was small, firm and jaundiced. The larger bile ducts were greatly dilated, and there was a stricture of the common duct above the cannula. (When the ulcer was cut through in the region of the ampulla, a ligature was encountered at the site of the intramural portion of the common duct.)

Microscopic Examination.—The histologic characteristics of both ulcers were similar. They were chronic perforated lesions, with evidence of attempted healing

Fig. 12 (dog 23-29).—Biliary obstruction, 108 days. Gastric erosion with hemorrhage; inflammatory reaction in submucosa. Reduced from × 30.

in one of them. The edges of the ulcers were overhanging and the surface was covered by amorphous cellular débris and polymorphonuclear leukocytes. Along one edge of the anterior ulcer there was a row of new proliferating epithelial cells. The base of this ulcer was formed by connective tissue. The base of the posterior ulcer was formed by connective tissue, pancreas, a lymph node and the wall of the sinus tract. In the antrum, there were numerous areas in which the surface epithelium of the villi was destroyed. The villi were small and coalesced, and stained homogeneously. There was no cellular reaction. The

liver showed dilatation of the bile canaliculi in the central portions of the lobules and central fatty degeneration of the liver cells. The Kupffer cells contained bile pigment.

Dog 23-29.—In a male airedale, weighing 15 Kg., a biliary fistula was produced. with cholecystectomy. Secretion continued for ten days, then stopped, and icterus appeared. Toward the end of the experiment, marked ascites, edema of the legs and hematemesis developed. The animal was killed on the one hundred and eighth day because of its poor condition.

Autopsy.—The tissues showed marked icterus. A large amount of clear, straw-colored fluid was present in the abdominal cavity. In the stomach, there were multiple acute ulcers in the antrum and on both sides of the magenstrasse. They varied in size from a few millimeters to 1.5 cm. and were found in the crypts between the folds of mucous membrane. They were covered with fresh blood clots. There were no lesions in the duodenum. The heart muscle was flabby. The mesenteric lymph nodes were hemorrhagic and enlarged. The kidneys were pale and contained cortical infarcts. The liver was greatly diminished in size, firm and icteric. The larger bile ducts were dilated, and there was a complete stricture of the common duct above the cannula.

Microscopic Examination.—The gastric lesions were erosions that extended through the mucosa and muscularis mucosae down to the inner circular layer. They occurred in the crypts between adjoining rugae. Sometimes the mucosa of the tops of the rugae remained intact, whereas in the depths there was extensive destruction of the epithelium. There was considerable undermining of the margins. The surface of the erosions was covered by blood clot, beneath which there was a layer of necrotic epithelium and leukocytes. In the underlying tissues, there was evidence of an intense inflammatory reaction with marked edema and fibrin deposit, infiltration with polymorphonuclear leukocytes and dilated capillaries and lymphatics. In the liver, the bile canaliculi were distended in the central portions of the lobules. There was proliferation of the smaller bile ducts and a marked increase of connective tissue causing extensive scarring and distortion of the liver lobules. There were numerous focal necroses and large cholangitic abscesses as well as pericholangitis and cholangitis of the larger bile ducts. The smaller ducts were not involved in the inflammatory process. The kidneys showed an occasional cellular cortical scar.

SUMMARY OF EXPERIMENTAL RESULTS

Group 1.—*Uncomplicated Biliary Fistulas.*—Seven animals were included in this series and were observed for periods extending from twelve to 102 days. Acute duodenal lesions were found in four dogs that died from twelve to sixteen days after the establishment of the fistulas. (One dog, 13-28, was killed on the twelfth day because of its poor condition.) In three animals, 509, 510 and 511, the lesions were single acute ulcers on the anterior wall of the duodenum. In one dog, 13-28, two erosions were found, one on the anterior and the other on the posterior surface. Perforation of the ulcer in dog 511 caused peritonitis and death. The three animals in which no lesions were found remained in good condition and were killed after fifty-two, fifty-three and 102 days, respectively.

The histologic examination of the livers of the animals in this group revealed few changes. In one dog, 21-28, the liver showed central fatty degeneration, pericholangitis and multiple abscesses.

GROUP 2.—*Biliary Fistulas Followed by Biliary Obstruction.*—Eleven animals were included in this series and were observed for periods extending from twenty-six to ninety-nine days. In six, lesions were found after twenty-six, twenty-nine, forty-six, fifty-six, eighty and ninety-nine days, respectively. In three dogs, 505, 506 and 508, single chronic ulcers were found on the anterior surface of the duodenum. In one dog, 2-29, a single subacute perforated duodenal ulcer was found on the anterior wall. In another dog, 34-29, there were multiple erosions of the stomach and duodenum. In dog 507, there were multiple subacute ulcers, one in the duodenum and two in the stomach; one of the latter had perforated. The ulcer in dog 505 showed evidences of healing.

The histologic examination of the livers of the animals in this group revealed changes that were associated with moderate biliary obstruction. Abscesses of the liver were found in three dogs, 507, 18-28 and 3-29; pericholangitis was found in one dog, 15-29.

GROUP 3.—*Biliary Obstruction.*—Five animals were included in this series and were observed for periods extending from thirty-three to 189 days. In three, lesions were found after forty-seven, 108 and 189 days, respectively. In one dog, 23-29, multiple gastric erosions were encountered. In another dog, 11-29, there were two perforated chronic duodenal ulcers. In the third animal, 5-29, there was a single chronic ulcer on the anterior surface of the duodenum. The ulcers in dogs 11-29 and 5-29 showed evidences of healing.

The histologic examination of the livers of all of the animals in this group showed changes caused by prolonged obstruction of the larger bile ducts. Abscesses of the liver were found in three dogs, 7-28, 5-29 and 23-29.

COMMENT

In a series of twenty-three dogs with various types of biliary exclusion, thirteen developed duodenal or gastric lesions. In ten animals, ulcers were found in the duodenum; in two, multiple gastric erosions occurred, and in one dog, both gastric and duodenal ulcers were observed.

It is interesting to note that a chronic duodenal ulcer was observed in dog 508 after an interval of twenty-six days. A similar observation was made by Mann and Williamson.[11] This suggests the possibility that in man, gastric and duodenal ulcers that have the histologic characteristics of chronic lesions may develop within a short period of time.

The condition of the gallbladder had no constant relationship to the incidence of ulcers. In groups 1 and 2, lesions occurred in animals with

11. Mann and Williamson (footnote 1, fourth reference).

intact gallbladders, with ligation of the cystic duct and with cholecystectomy. In group 3, ulcers were found only in the dogs whose gallbladders had been removed.

Abscesses of the liver and pericholangitis occurred in some of the animals, but these lesions did not seem to have any influence on the development of ulcers.

INCIDENCE OF ULCERS AND ENVIRONMENT

The animals in groups 1 and 2 were studied under different environmental conditions. During the early part of the investigation, dogs 509, 510 and 511 of group 1, and 505, 506, 507 and 508 of group 2 were kept in old laboratory quarters. It was difficult to maintain cleanliness, and the floors were damp because of inadequate drainage. Although the constituents of the food were mixed and the quantity was plentiful, the preparation was poor and the utensils were insanitary. The ingredients of the food had to be changed frequently because the animals refused to eat. They lost weight rapidly and died early. Under these conditions, the incidence of ulcers was nearly 100 per cent. On the other hand, during a later period of the investigation, dogs 13-28, 31-28, 10-29 and 22-29 of group 1, and dogs 17-28, 18-28, 2-29, 3-29, 15-29 and 34-29 of group 2 were housed in new quarters. The cages were kept dry and clean. The diet was prepared carefully in clean utensils. The dogs remained in good condition and lived for relatively long periods. Under these improved conditions the incidence of ulcers dropped to 30 per cent.

Although this was a small series of animals, it was noteworthy that in an unfavorable environment the incidence of ulcers was much higher than that under more favorable conditions. It was not possible to make a similar comparative study of the animals of group 3 because most of them were studied only in favorable surroundings. Nevertheless, ulcers developed in 60 per cent of the animals in this group.

RÔLE OF MUCUS

The mechanism by which the exclusion of bile predisposes the mucosa to ulceration depends probably on the loss of some constituent in the bile which is essential for the maintenance of an intact surface epithelium. The component of the bile that can serve this purpose most readily is the mucus because of its physicochemical properties. Beaumont,[12] Claude Bernard [13] and Pavlov [14] observed that the healthy

12. Beaumont, W.: Experiments and Observations on the Gastric Juice and the Physiology of Digestion, Plattsburgh, F. P. Allen, 1833, p. 103.

13. Bernard, Claude: Physiologie expérimentale, Paris, J. B. Baillière et fils, 1856, vol. 2, p. 408.

14. Pavlov, I.: The Work of the Digestive Glands, London, Griffin & Company, 1910, p. 238.

mucosa was always covered by a layer of mucus and suggested the protective function of this secretion. It is noteworthy that the duodenum which receives the acid gastric fluids and requires more protection for its surface epithelium than any other segment of the gastro-intestinal tract is supplied with mucus derived from four sources: the bile, the pancreatic juice, the intestinal mucous glands and Brunner's glands.[15] The pyloric region is composed entirely of mucous glands.[16] The relative importance of the mucus contained in the bile compared to the mucus in the other duodenal fluids is unknown, but there is probably a close interrelationship between them. One of the effects of biliary exclusion may be the disturbance of the regulatory mechanism of mucous secretion which exposes the surface epithelium to the action of the gastric juice.[17]

CONCLUSIONS

The results of this investigation suggest the possibility that alterations in the function of the liver and in the secretion of bile may be important factors in the etiology of peptic ulcers. Although gross or microscopic changes in the biliary tract are found in only a small percentage of cases of ulcer in man,[18] nevertheless, functional disturbances that are not recognized by present inadequate methods may exist. The periods of remission and exacerbation that characterize so-called chronic ulcers may coincide with intermittent functional alterations in the stomach and duodenum in response to changes in the liver and biliary system. If peptic ulcers are associated with deficiency of the liver in man, the administration of liver may be of therapeutic value. A clinical study is in progress to determine the efficacy of this form of treatment. The results obtained from these preliminary studies suggest that treatment with liver does have a beneficial effect, but the studies have not been carried on for a sufficient length of time to enable us to form definite conclusions.

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15. Bensley, R. R.: The Structure of the Glands of Brunner, Decennial Publications, University of Chicago, 1903, vol. 10, p. 279.

16. Bensley, R. R.: The Structure of the Mammalian Gastric Glands, Quart. J. Micr. Sc. **41**:361 (Nov.) 1898. Lim, R. K. S.: The Gastric Mucosa, Quart. J. Micr. Sc. **66**:187 (June) 1922.

17. Schmidt, A.: Ueber die Schleimabsonderung im Magen, Deutsches Arch. f. klin. Med. **57**:65 (May 28) 1896. Kaufmann, J.: Mangel an Magenschleim (Amyxorrhoea gastrica) seine pathologische Bedeutung und seine Beziehungen zur Hyperacidität und zum Magenschwür, Arch. f. Verdauungskr. **13**:616 (Dec. 20) 1907. Foster, N. B.: The Chemical Affinity of Mucus for Hydrochloric Acid, Am. J. M. Sc. **133**:303 (Feb.) 1907.

18. Sherwood, W. A.: Surgical Lesions of the Biliary Tract, Ann. Surg. **88**:178 (Aug.) 1928.

DIAPHRAGMATIC ADHESIONS *

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In this paper I shall point out in what manner adhesions between the diaphragm and the wall of the chest can act to further the healing of pulmonary tuberculosis and how, in their presence, the production of diaphragmatic paralysis may be harmful rather than beneficial.

As a basis for this consideration, one must accept the fundamental proposition that movement of a tuberculous lung discourages healing while rest favors it.

Since the time of Galen there has been active discussion concerning the effect of contraction of the diaphragm on the ribs to which it is attached. Galen [1] believed that it raised them slightly. Borelli [1] and later von Haller [1] were of the opinion that it tended to draw them downward. In 1853, Duchenne,[2] of Boulogne, presented the results of experiments on dogs, horses and human beings, which seemed convincing substantiation of the earlier conception of Galen. In 1896, Gerhardt,[3] while admitting the probable correctness of Duchenne's views, called attention to the fact that anything tending to lower the dome of the diaphragm or to raise its attachment to the wall of the chest might so change the direction of its pull on the ribs as to draw them downward on inspiration. Between 1918 and 1924, Hoover,[4] reported the results of numerous clinical observations and experiments on dogs which directly controverted those of Duchenne and substantiated the observations of Borelli, von Haller and Gerhardt.

The essence of Hoover's conclusions is that the contracting diaphragm exerts a medianward rather than an upward pull on the lower ribs, and consequently acts as an antagonist of the muscles tending to elevate and spread them. He observed repeatedly in human beings and dogs that paralysis of the hemidiaphragm was followed by an increased upward movement of the lower ribs on the affected side and a widening of the subcostal angle. Stimulation of the nerve caused a narrowing

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* Submitted for publication, Oct. 20, 1929.

1. Galen; Borelli, and von Haller, cited by Duchenne: Union Med. **7**:105, 1853.

2. Duchenne: Union Med. **7**: 105, 1853.

3. Gerhardt: Ztschr. f. klin. Med. **30**:37, 1896.

4. Hoover, C. F.: The Functions of the Diaphragm and Their Diagnostic Significance, Arch. Int. Med. **12**: 214 (Aug.) 1913.

of the lower part of the thorax, except in the exceptional instance in which the dog had a very small subcostal angle and a high diaphragmatic arch.

He maintained that under normal conditions the muscles tending to elevate the ribs were able to overcome the antagonism of the diaphragm; but in his clinical observations he found, in accord with Gerhardt, that pathologic factors tending to lower the dome of the diaphragm or raise its attachment to the ribs so increased its medianward pull that the lower ribs were drawn medianward on inspiration. He noted especially that high adhesions between the diaphragm and the wall of the chest could bring about this paradox.

Experimental and clinical observations of my own (to be published soon) have, in the main, substantiated the work of Hoover.

The diaphragm, arising from the six lower ribs, the lumbar vertebrae and the ensiform cartilage, arches upward and medianward to its insertion in the central tendon. It is maintained in its domelike shape by the negative intrapleural pressure, the pericardial ligaments, the positive intra-abdominal pressure and the support of the abdominal viscera. For a considerable distance above its origin its upper surface coheres to the thoracic wall. Neither its origin nor its insertion are fixed points. Contracting thus around an arc, in what direction it exerts its force on the ribs to which it is attached must depend on the ratio between the height and the breadth of the arch. The higher the dome, the more the pull will be upward, the lower the dome, the more medianward. At the beginning of inspiration the upward factor must be at its maximum. As inspiration proceeds and the dome descends and the ribs rise, the median pull must increase proportionately.

From this it is obvious that adhesions between the diaphragm and the wall of the chest make more direct the medianward pull by raising the origin of the muscle, and so decreasing the height of the arch. Not only do they bring the diaphragm into more direct antagonism to the muscles tending to elevate the ribs, but they limit the descent of the diaphragm itself. They act thus to decrease both costal and diaphragmatic breathing. If, as not infrequently happens, the adhesions are on a level with the dome, or even higher, the diaphragm is wholly prevented from descending, and the entire force of its contraction is exerted in drawing the ribs downward and medianward, with the result that on inspiration they are moved paradoxically in this direction. The adhesions prevent descent of the diaphragm and the diaphragm prevents expansion of the bony thorax. The resulting immobility must be assumed as being favorable to the healing of tuberculous lesions.

If, under these conditions, the diaphragm is paralyzed by extraction of the phrenic nerve, respiration in the lung must be increased. The

diaphragm, fixed already in an expiratory position and contributing little to respiration, has been functioning chiefly in restricting the movement of the ribs. Its paralysis serves only to mobilize the ribs and allow them to function normally. It does not throw the dome into a higher position or alter appreciably its excursion.

REPORT OF CASES

CASE 1.—Mr. J. L., single, an American laborer, aged 40, came to the dispensary of the Research and Educational Hospital complaining of the usual symptoms of pulmonary tuberculosis of two years' duration. A year before, he had developed pleurisy with effusion of the left lung and had been treated by repeated aspirations. Physical, roentgen and sputum examinations confirmed the diagnosis of bilateral pulmonary tuberculosis. The roentgenogram showed high adhesions between the left side of the diaphragm and the thoracic wall. Examination with the fluoroscope showed no descent of the left diaphragm. On physical examination, it was found that movement of the ribs throughout the left thorax was markedly restricted, and that on inspiration the lower ribs moved downward and inward, paradoxically. The patient complained of inspiratory pain in this region.

On March 2, 1929, the left phrenic nerve was extracted. Observation of the respiratory movements after the operation revealed a marked increase in the movement throughout the affected side. The lower ribs now moved in the normal direction on inspiration, and the pain which had been present previous to the operation had disappeared. There was little, if any, further elevation of the diaphragm.

CASE 2.—Mr. J. C., single, American, an office worker, aged 30, entered the Research and Educational Hospital of the University of Illinois, complaining of a draining sinus of the left axillary region. On the basis of clinical and roentgenologic examinations, a diagnosis of chronic empyema was made. Following a course of irrigations, he was operated on, and a cavity was found which was bounded below by the diaphragm and extended upward and posteriorly under the scapula. The ribs and the intercostal tissues overlying it were resected, and the wound was packed. Healing progressed satisfactorily, except that a small sinus persisted.

Six months later, the sinus was still present, and examination at this time showed that on inspiration the area of the old wound was drawn forcibly inward and downward, and that there was a paradoxic movement of the ribs of the entire lower thorax. The movement of the upper ribs was markedly restricted. It seemed obvious that these phenomena were caused by the pull of the adherent diaphragm, and that the continuous intermittent tug was a factor in preventing healing of the sinus. For this reason, the left phrenic nerve was extracted. Following the operation, the area of the wound was no longer pulled inward on inspiration, and the movement of the upper ribs was markedly increased. The discharge from the sinus showed a decrease of 50 per cent. The vital capacity, which before the operation had been 1,600 cc., was raised to 1,700 cc.

In this case high adhesions between the diaphragm and the wall of the chest produced a paradoxic movement of the lower thorax. This was reversed by paralyzing the diaphragm, with the result that the vital capacity was increased rather than reduced.

EXPERIMENTAL EVIDENCE

Although Gerhardt and Hoover concluded that high adhesions between the diaphragm and the wall of the chest limited thoracic excursion and although Hoover verified this by observations on dogs, the phenomenon had not been recorded graphically. For this reason, the following experiment was performed.

PROTOCOL.—A male police dog, weighing 22 pounds (10 Kg.), was given an ether anesthesia. Through an upper abdominal incision, the right dome of the diaphragm was sutured to the wall of the chest at the level of the fourth rib in

The upper tracing shows the respiratory excursions of the left hemithorax; the lower tracing, those of the right hemithorax, which had been restricted by the production of adhesions between the diaphragm and the wall of the chest. At the point *X*, the right phrenic nerve was cut. This was followed immediately by a marked increase in the excursion of this side of the thorax.

the midaxillary line. Three mattress sutures were passed through the diaphragm and the wall of the chest, so that the free ends hung on the outside of the body, and each suture when tied surrounded a rib. The right phrenic nerve was exposed in the neck and the costochondral junction of the two sixth ribs was laid bare for the attachment of the recording apparatus. Threads were fastened to these two points and carried downward above the dog's body and over pulleys, and finally were attached to the muscle levers in such a manner that an upward movement of the ribs would produce an upward movement of the levers, and vice versa. The

levers were adjusted to make tracings on a revolving smoked paper. The upper lever recorded the movements of the left side of the thorax, and the lower lever, those of the right side.

A normal tracing was taken (figure), which showed a marked limitation of movement of the hemithorax in which the adhesions had been produced. Following section of the right phrenic nerve, the movement of the ribs on this side was immediately and greatly increased.

SUMMARY

Adhesions between the diaphragm and the wall of the chest restrict markedly the respiration of the homolateral lung.

In the presence of such adhesions, induction of paralysis of the hemidiaphragm may so increase the costal movements on that side that the vital capacity is increased rather than decreased.

It is suggested that the presence of such adhesions favors the healing of tuberculous lesions in the lungs and should be considered as a contraindication to the operation of phrenico-exeresis.

AN OPERATION FOR THE TREATMENT OF SPASMODIC TORTICOLLIS *

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It would seem that spasmodic torticollis had run the gauntlet of therapeutic efforts, surgical, medical and psychic. With one exception, the surgical methods have appeared after one or two trials and after an all too brief test of time. And, with this exception, the lack of later reports by the authors is in itself almost adequate evidence that the procedures have ended in failure, as indeed they must. Again, with this one exception, the surgical procedures have been unilateral. Regardless of one's interpretation of the underlying spasmodic contractures, one fact is incontrovertible, i. e., the disease is never restricted to an isolated muscle or to a single group and never to the muscles of one side.

To one not acquainted with the subsequent history of cases of this type, it is indeed difficult to understand why the simple excision of a preponderant, rigid, sternomastoid muscle, which dominates the clinical picture, or better still, the division of the spinal accessory nerve supplying it and the trapezius muscle, will not correct the condition. But these efforts have long since been found to do little more than to afford at best a brief respite. Soon the muscles on the contralateral side pulled the head just as strongly, and when a similar procedure was carried out there, other muscles quickly produced spasmodic contractures just as severe and unrelenting as the original. Attempts of this character were more or less in vogue, though unsuccessful, when Keen,[1] America's pioneer neurologic surgeon, realizing the more widespread involvement of the cervical muscles of rotation, first (1891) divided on one side the posterior divisions of the first, second and third cervical nerves at their points of emergence from the vertebrae. It is interesting that Keen's surgical effort was advised by Wier Mitchell, from whom a functional basis for spasmodic torticollis would not have been unexpected. Taylor[2] (1915) reported unilateral division of the upper four sensory cervical nerves by the first intraspinal attack for this condition. His procedure was proposed on the basis of Foerster's

* Submitted for publication, Dec. 31, 1929.

* From the Johns Hopkins University and Hospital.

1. Keen, W. W.: A New Operation for Spasmodic Wry Neck—Namely Division or Exsection of the Nerves Supplying the Posterior Rotator Muscles of the Head, Ann. Surg. **13**:44, 1891.

2. Taylor, A. S., in Johnson: Surgical Therapeutics, 1915, vol. 1, p. 525.

treatment in Little's disease by reduction of the incoming sensory stimuli. McKenzie [3] (1924) carried the intraspinal divisions of the nerves a step farther, sectioning the upper three motor and sensory nerves and the spinal accessory nerve—all on one side only.

In the following year (1925), Finney and Hughson [4] reported the first bilateral operation. It had been used in thirty-one cases over a period of twenty years; twelve patients were cured, sixteen were improved and three were unimproved. Both spinal accessory nerves and the posterior divisions of the upper three cervical nerves on both sides were divided. The former were sectioned alongside the sternomastoid muscles, the latter at the points of emergence from the spinal vertebrae. The operation was, in effect, a bilateral Keen's operation plus division of both spinal accessory nerves. These were the first cases of torticollis in which cure was reported, the reason doubtless being that for the first time a number of nerves had been sectioned bilaterally. Moreover, they were the first cases in which the operative results were adequately tested by time. That cure was not obtained in all cases was due to a number of factors, principally, no doubt, to the individual variations in the extent of involvement of the cervical muscles.

The etiology and pathology of spasmodic torticollis are not known. The explanation of the disease is beset with many theories which it is needless to repeat. None is satisfying. I have nothing to contribute to this phase of torticollis; my only strong conviction is that spasmodic torticollis is undoubtedly of organic and not of functional origin. Certainly in the group which I have observed there has been no greater evidence of a psychogenic background than in any other group of lesions subjected to surgical treatment. This, I am sure, is also Finney's strong impression in his larger series of cases. Even could a functional basis be entertained, certainly no treatment along these lines has offered results at all comparable with those obtained by the operation of Finney and Hughson.

AUTHOR'S OPERATION

Greatly impressed by the ultimate results of Finney's long struggle with torticollis, it occurred to me that much the same results could perhaps be obtained more simply and easily by attacking the same nerves centrally, i. e., alongside the spinal cord rather than at the periphery. Seven patients have been operated on by this method. Through a high cervical laminectomy in which the laminae of the upper three vertebrae are removed, the sensory and motor roots of the first, second and third

3. McKenzie, Kenneth G.: Intrameningeal Division of the Spinal Accessory and Roots of the Upper Cervical Nerves for the Treatment of Spasmodic Torticollis, Surg. Gynec. Obst. **39**:5, 1924.

4. Finney and Hughson: Spasmodic Torticollis, Ann. Surg. **81**:255, 1925.

cervical nerves are resected (fig. 1). Until recently, both spinal accessory nerves were divided alongside the medulla, and the higher medullary branches were also divided independently with a tiny knife. But recently, this part of the operation has been discarded because it is not always possible to get the anteriormost filaments. It has, therefore, seemed better to divide the spinal accessory nerve intraspinally at the level of the foramen magnum only in order to expose better the first cervical motor branch. When the operation is concluded, the patient is turned on the back, and through two small incisions in the neck the spinal accessory nerves are exposed and divided, and the central ends are reversed and sutured in this position to avoid regeneration (fig. 2). Separate section of the spinal accessory nerves requires only a few moments and is, I think, much better than intracranial division of these nerves at the jugular foramen as carried out by McKenzie in his unilateral procedure. To divide this nerve at the jugular foramen, an extra bony defect of considerable magnitude must be made in the occipital bone.

In earlier cases, the outcome of function of the sternomastoid and trapezius muscles was awaited, and at a later date the spinal accessory nerves were divided, when necessary, under local anesthesia. Although the upper three cervical sensory roots had been sacrificed and the cutaneous sensation abolished, there is usually some pain in exposing the spinal accessory nerves. Doubtless this pain is of sympathetic origin. It is quite variable, however; in one case there was no sensation throughout the dissection of both nerves; in another there was some but not much pain, and in a third the pain was quite severe throughout. In the latter case and two others, the postoperative function of the sternomastoid muscle had persisted on one side only.

Intradural division of the sensory and motor nerves is easy to perform and is practically devoid of danger to life or function. Loss of function in the affected muscles and in sensation of the skin are absolutely total and permanent, because neither the motor nor the sensory nerves can possibly regenerate.

I am not convinced that cutaneous anesthesia is of any value in determining the course of torticollis. In one of the earlier cases, the fourth, fifth and sixth sensory roots were also sectioned in a longer laminectomy. It has appeared necessary to divide the upper three sensory roots in order to have access to the motor roots. However, it is quite possible that sufficient retraction of the sensory roots may be obtained to permit sacrifice of the motor roots only. An effort will be made to determine the practicability of subsequent cases attaining this end. It will doubtless be difficult, because the sensory roots are short, run transversely and are directly over by the motor roots. The first cervical sensory root is variable and probably of little concern.

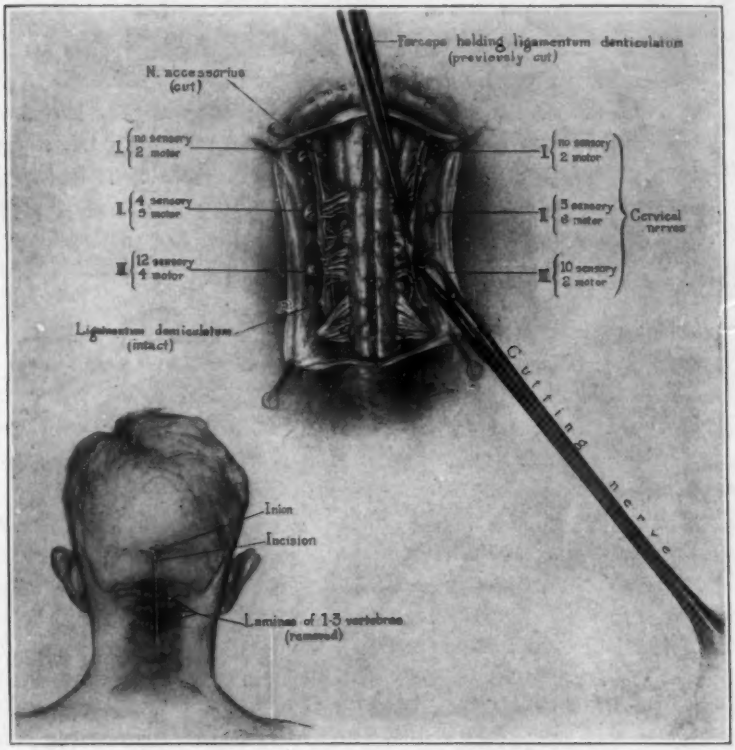

Fig. 1.—Operative procedure by which the upper three cervical sensory and motor nerves are divided on both sides intraspinally. The instrument shown cutting the nerve was devised by Dr. Trimble. It is a combination nerve hook and scissors.

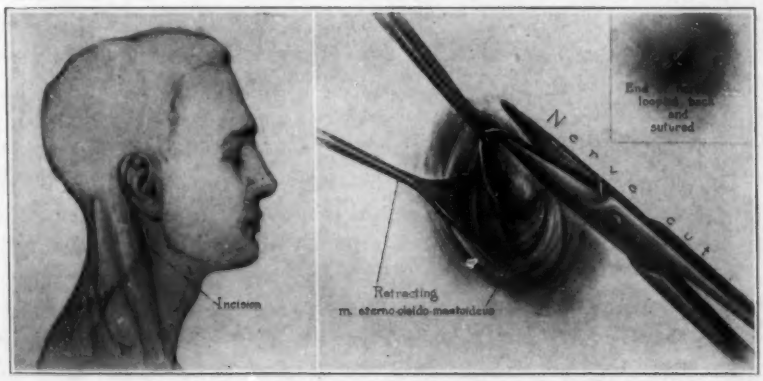

Fig. 2.—Separate incision used to expose and divide the spinal accessory nerve in the neck on each side. It is sutured in reverse in order to prevent regeneration.

In three of our cases it was absent on both sides, and in one case it was present on one side only.

Although the perverted function of chief concern in spasmodic torticollis is rotation of the head and neck, there may be associated strong flexion, extension or lateral traction. Practically all of the muscles performing rotation when acting singly also produce flexion or extension when acting together. There are, in fact, few muscles attached to the head and neck which do not in some degree perform either flexion or extension in addition to rotation, or inversely they perform some degree of rotation in addition to the predominant function of flexion or extension. The exact amount of rotation at any time depends on the leverage obtainable by the attachment of the muscle to the head or neck. Muscles such as the longus colli, and the scalenus medius are too strictly median to permit of more than a minimal degree of rotation when acting singly. The larger semispinalis capitis (complexus) muscle, though mesially placed, has such a wide attachment to the skull that when acting singly a fair degree of rotation must result in addition to its predominant function of extension. Even the group of small suprahyoid muscles must play a minor rôle in rotation, flexion and extension of the head and neck.

In looking at the problem of torticollis from an anatomic standpoint, it is, therefore, evident that practically all the muscles of the head and neck must be taken into consideration. It is, of course, entirely unpractical to put them all out of commission in order to obtain a cure. Fortunately, this is unnecessary. Finney's proposal, which has proved so successful, has demonstrated that if the functions of the major rotators are eliminated, in whole or in part, the remaining muscles are for all practical purposes adequate to take care of the required movements of the head and neck, and by their training subsequent to the operation, the torticollis can be overcome entirely or nearly so. Fortunately, also, the empiric results of Finney and Hughson have shown that it is only necessary to divide the spinal accessory nerves and the upper three cervical motor roots to attain this.

In most cases, at first, the head seems a little insecure and lacking in support, but this deficit is gradually overcome when the intact or partially preserved muscles are used as a result of training. After a few months scarcely any residual muscular loss can be detected, subjectively or objectively. A glance at the accompanying table will show exactly how far the removal of this nerve supply affects these muscles. The function of the entire group of small muscles between the occiput, atlas and axis is entirely abolished. The remaining muscles are entered in their probable importance as rotators of the head and neck. It will be seen that some of the larger muscles retain part—even a large part—of their nerve supply after the operation and therefore function in restricted degree. Of the more important muscles of rotation, only

the functions of the sternomastoid and trapezius and splenius cervicis, the longissimus capitis and cervicis, the semispinalis capitis and the levator angulae scapulae and the group of scaleni muscles are affected only in part.

Muscles Involved in Torticollis

Group I:	Muscles	Nerve Supply	Function After Operation
Small muscles between the atlas, axis and the occiput	Rectus capitis anterior Rectus capitis lateralis Rectus capitis posterior major Rectus capitis posterior minor Obliquus capitis inferior Obliquus capitis superior	First and second cervicals	Abolished
Group II:			
Larger muscles of neck (arranged in order of importance)	Sternomastoid	Spinal accessory, second and third cervicals	Abolished
	Trapezius	Spinal accessory, second and third cervicals	Abolished
	Splenius capitis	Second and third cervicals	Abolished
	Splenius cervicis	Fourth to eighth cervicals	Unaffected
	Levator anguli scapulae	Third and fourth cervicals	Only partially lost
	Longissimus capitis	Second to fifth cervicals	Partially lost
	Longissimus cervicis	Fifth to eighth cervicals	Unaffected
	Semispinalis capitis (Complexus)	Second to eighth cervicals	Partially lost
	Longus capitis	First, second and third cervicals	Abolished
	Scalenus anterior Scalenus medius Scalenus posterior	Second to seventh cervicals	Slightly affected
Group III:			
Muscles of deglutition, many of which play a minor rôle in rotation of the head and some are affected by section of the cervical nerves	Digastric	Fifth and seventh cranials	Unaffected
	Stylohyoid	Seventh cranial	Unaffected
	Mylohyoid	Fifth cranial	Unaffected
	Geniohyoid	Twelfth cranial	Unaffected
	Geniohyoglossus	Twelfth cranial	Unaffected
	Hyoglossus	Twelfth cranial	Unaffected
	Thyrohyoid	Twelfth cranial	Unaffected
	Sternohyoid	First, second and third cervicals and twelfth cranial	Affected
	Omohyoid	First, second and third cervicals and twelfth cranial	Affected
	Sternothyroid	First, second and third cervicals and cranial	Affected

The retention of muscular function obviously explains the failure to obtain complete cure in all cases of torticollis; in some cases the result has fallen just short of complete cure and in practically all tremendous improvement has been secured. This statement is based on the results in the cases of Finney and Hughson and my own.

The limits of intraspinal section of the cervical nerves are reached by the operation here reported. Since the fourth cervical nerves give

rise to the phrenic nerves and the remaining cervical nerves to the branchial plexus, they must be left intact. In those more refractory cases which retain some degree of imperfection after operation, it is possible to pick out more readily a single or small group of offending muscles and remove their nerve supply by a minor peripheral operation. In one of my cases the head is entirely quieted, but the levator angulae scapulae muscle continues to act. As this muscle receives its nerve supply from the third and fourth cervical nerves, its function is partly retained after the intraspinal operation. Improvement should be anticipated by peripheral division of the branch of the dorsalis scapulae nerve.

REPORT OF CASES

Group 1: Cases in Which Cure is Reported.—CASE 1.—A physician, aged 40, four years before being operated on for spasmodic torticollis, experienced a slight aching pain in the lower cervical vertebrae, which tended to be transmitted around both sides of the neck. At that time, she paid little attention to it. During this attack, the head began to draw to the right and backward, both steadily and spasmodically. Relief was obtained by allowing the head to hang over the edge of the bed. Over a period of two years, the symptoms gradually disappeared—the shaking first, the pain later. For a year and a half, she was quite well. Four months before operation, the head again began to draw to the left instead of to the right, as in the first attack. This state of powerful contraction of the rotator muscles persisted without signs of relenting. If the head was forcibly drawn to the other side, it returned in a few seconds. At times, there was numbness in both arms. Until two months before, there was a sore spot at the base of the neck on the left side.

Examination.—Aside from the local condition, there were no objective signs. The head was strongly drawn to the left and slightly backward. The sternomastoid muscles seemed to preponderate.

Operation.—April 11, 1928: The spinal accessory, the first, second and third motor roots and the upper five sensory roots (the first sensory root was absent on both sides) were sectioned intraspinally.

Subsequent division of the left spinal accessory nerve in the neck was necessary in this case.

Result.—After operation, there were minor jerkings of the head. These were gradually overcome during the next few months. Since then, the patient has been free from symptoms.

CASE 2.—An army officer, aged 40, had torticollis, with turning of the head to the left, for the past two years. Previous to the onset of this trouble, he had had two or three attacks of "crick in the neck" each year. Sixteen years before, one of these attacks kept him bedfast for several days; four years before another equally severe attack was followed three days later by an excruciating "neuritis" in the left arm, lasting for a month. Throughout the duration of the torticollis, the head had drawn steadily to the left. He could counteract it only by holding the hand on the head. There were no spasms. The examination revealed nothing except the local condition. The head was drawn strongly to the left; efforts to correct this position caused the head to jerk. The left sternomastoid muscle was drawn like a tight cord across the neck.

Operation.—Nov. 26, 1928: Laminectomy of the upper three cervical vertebrae was performed. The spinal accessory nerves and the upper three cervical motor and sensory nerves on both sides were sectioned intradurally. Subsequent division of the spinal accessory nerves in the neck was unnecessary.

Result.—Immediately after the operation, the same tendency to draw the head to the left was evident at times; there was also some unsteadiness of the head. The patient spent several months abroad and returned free from all symptoms and has so remained to date. He has resumed his occupation.

CASE 3.—An accountant, aged 47, had been troubled with a stiff neck for eight years. One year earlier (nine years before operation), a dull pain persisted along the right side of the neck for several months, finally disappearing. One year before, his head began to draw to the right. Six months before, the head began to draw to the left and the left shoulder began to elevate.

The results of the examination were negative, except for the outspoken torticollis with rotation to the left.

Operation.—March 20, 1929: Cervical laminectomy was performed. The spinal accessory and the first, second and third sensory and motor roots on both sides were sectioned intradurally. Before the patient left the hospital, the left spinal accessory nerve was divided in the neck.

Result.—Unsteadiness of the head persisted in slight degree for two or three months, gradually abating. Immediately after operation, the patient complained of some subjective difficulty in swallowing, but aside from some tardiness there was no objective evidence of dysphagia. There has since been improvement but not entire correction.

CASE 4.—A sparely nourished woman, aged 61, presented a most remarkable picture of torticollis. When lying in bed, her head was quiet and could be maintained in any position, but immediately on assuming a sitting posture her head would snap with great violence. Although the most common direction of the sudden thrust of the head was to the right, it was frequently to the left; at other times, backward and forward. She was never able to swallow when sitting or standing unless the head was strongly supported. With the head at rest in the recumbent position, there was no dysphagia. She dated her trouble to a so-called nervous breakdown five years before. She had been weak and nervous and unable to carry on any longer. Two months later, pain and jerking appeared in the neck. It was intermittent at first, but recently had become incessant when she was not in a recumbent position.

Operation.—Oct. 31, 1929: Tribromethylalcohol anesthesia was administered by rectum. Both spinal accessory nerves and the first, second and third sensory and motor nerves on both sides were sectioned intraspinally. Two weeks later, both spinal accessory nerves were divided without any anesthesia and absolutely without pain, except when the spinal accessory nerves were handled. This pain was referred to the ear and angle of the jaw.

Result.—The patient remained in the hospital one month. She was practically devoid of involuntary movements of the head or neck at all times after the operation.

CASE 5.—A fairly well nourished man, aged 59, referred the onset of his trouble to a spell of constant pressure and stiffness in the back of the neck. This occurred four years before operation for torticollis, lasted six months and disappeared completely. Soon thereafter, sudden attacks of intermittent spasms of the muscles of the neck caused rotation of the head to the right every two or three minutes. Gradually, the attacks fused and strong rotation of the head

persisted to the right. Shortly after the onset of his trouble, he had difficulty in swallowing. This became so severe that he could scarcely take any nourishment, and in two weeks he lost 20 pounds (9 Kg.). Without apparent reason, swallowing gradually improved and finally became normal. It was, however, always necessary to steady the head with his hand in order to permit swallowing. The contractions were said to cease during sleep, but the rotation of the head to the right persisted. The platysma contracted during the attacks, and athetoid-like movements of the hands and arms participated.

Operation.—April 20, 1925: The spinal accessory, first, second and third cervical and sensory nerves on both sides were sectioned intradurally.

This was one of the most severe cases of the series. Three months before this operation, the patient had been operated on by Dr. Finney. He seemed so little improved that at Dr. Finney's suggestion I cut the nerves intradurally for the first time. On discharge from the hospital three weeks later, the patient was considerably improved though far from well. I have not seen him since then and was fully prepared to be told, in response to an inquiry, that he was still affected. The following excerpts from his letter (Dec. 1, 1929), however, lead me to include him with the patients cured: "I have been doing very well. My neck does not pull or jerk any more. . . . I weigh 143 lbs.; the best I ever weighed was 153."

This case well emphasizes the importance of time and practice in overcoming the traces of the malady which still linger after the operation. I am, therefore, not at all sure that the same results might not well have followed Dr. Finney's operation had he been given the advantage of the same period of time for recovery.

Group 2: Cases in Which Great Improvement but Not Cure Is Reported.—Case 6.—A school teacher, aged 41, had severe tension of the head to the left and downward. Although the head was always strongly rotated, there were frequent superimposed spasms. Voluntary efforts increased the unsteadiness of the head. She dated her trouble to a "nervous strain" a year before. Soon thereafter, the head began pulling to the left. Recently, the character of the attacks changed. The head drew to the right and backward. A rest cure of eight weeks seemed to bring some improvement, but it was slight and very transient. A brace between the head and shoulders was worn for two weeks without appreciable benefit. Contractions were worse when she was lying down. Her voice was greatly affected for some time, and she was able to talk only in a whisper for several weeks.

Operation.—Nov. 14, 1928: Both spinal accessory, the first, second and third cervical sensory and the motor roots on both sides were sectioned intradurally. Three months later, with the patient under local anesthesia, the right spinal accessory nerve was divided in the neck. Although the skin was anesthetic from the loss of sensory nerves, it was necessary to use procaine hydrochloride freely in the deeper approach to the spinal accessory nerve. Section of this nerve produced a sharp deep pain in the ear and at the angle of the lower jaw.

Result.—The head is perfectly still, but the neck continues to draw to the left and to rotate slightly. The muscle involved is undoubtedly the levator anguli scapulae; perhaps the scaleni are also involved. The end-result of this strong muscular pull is a curvature of the neck. The patient has subconsciously overcome the curvature by a counter pull and holds the head erect without conscious effort. She feels so well that she is unwilling, for the present at least, to have

the nerve to the levator anguli scapulae muscle divided in the neck. She is again teaching school. Her voice, though still not normal, is greatly improved and carries without apparent effort.

CASE 7.—A sparely nourished man, aged 54, a bookkeeper and accountant, first noticed jerking of the right shoulder upward and forward when writing two years before operation. Sixteen months before, his head drew downward and to the right, remaining there all day. A few days later this contraction was repeated, and since that time the head had remained almost constantly down in that position when the patient sat or stood. Partial relaxation occurred when he was in a recumbent position. Jerking developed only when he attempted to correct the position of the head. Relief was obtained when his mind was diverted; it was intensified by nervous strain.

Operation.—Oct. 9, 1928: The spinal accessory, first, second and third cervical sensory and motor roots on both sides were sectioned intradurally. Ten days later, with the patient under local anesthesia, the right spinal accessory nerve was divided in the neck.

Result.—This is the only case in the series in which unsatisfactory results were obtained. Objectively, the patient is tremendously improved, certainly more than the patient in the preceding case. Indeed, with very little effort on his part, the slight rotation which exists could easily be overcome by voluntary effort. He is the only psychoneurotic patient of the series. His chief complaints now are sensory rather than motor, the most serious trouble being a sensation of a steel bar that is constantly separating his shoulders and holding them apart. Pains were constantly present in the neck and head. Being most introspective, he is continually striving to find an underlying cause for his symptoms, experimenting with medicines and seeking the advice of numerous physicians. A background of serious family and financial troubles has added greatly to the somatic psychosis. He cannot be induced to make any effort to readjust himself to his family or to renew his work.

RESULTS OF THE OPERATION

Of the eight patients included in this effort, five appear to be practically cured; two fall short of a complete cure but are greatly improved; the remaining one is not living. In four of the cases in which cure has been recorded, the patients have been personally examined from time to time since the operation. The lapse of time since the operation is twenty, fourteen, nine and two months. These patients have consistently improved since the operation, and without exception have had no recessions. All patients, with the exception of the one operated on recently, have returned to work. Perhaps it is not justifiable to include the last case in which only two months have elapsed since operation. My reasons for doing so are that this case was tne most severe in the group, and the patient was more perfectly relieved immediately after the operation than any of the others. The fifth patient considered as cured has not been seen since the operation. The inclusion of this case in the group in which cure was obtained is based on the patient's letter in which he stated that his head no longer jerks and draws. He was the first patient operated on by this method.

The two patients who were not completely cured are greatly improved. Perhaps a conservative estimate of the improvement in these patients, whom I have observed from time to time, would be about 85 per cent. The degree of objective improvement is about the same in each instance, and in each the levator anguli scapulae muscles (possibly the scaleni are partly at fault) seem to be the cause of failure to obtain complete cure.

There has been no operative mortality in the series. The single death occurred three weeks after operation, and was due to pneumonia contracted ten days after the operation. During the first ten days the patient was entirely free from fever, a fact which eliminates the anesthetic as the cause. He was a very bad surgical risk, having auricular fibrillation and advanced myocarditis, but he was so miserable that we were prevailed on to accede to his urgent wish for the operation.

In only one instance has there been entire freedom from minor jerking or drawing of the head immediately after the operation. The movements, however, lack the tremendous force of the preoperative state. Nevertheless, the mere existence of the same muscular effects after the operation will have a severe psychologic effect on patient and surgeon alike if its existence and import are not realized. The patient should be prepared in advance to know that the resultant cure will not be instantaneous. After convalescence from the operation, the patient should be induced, if possible, to spend from three to six months in rest and in graduated exercises which will strengthen the muscles of the neck. Finney and Hughson emphasized the importance of the postoperative period of training in eliminating the last traces of muscular incoordination.

Mention should be made of a minor degree of dysphagia which was noticed in two of my patients. It is noticed principally in swallowing solids. The act of deglutition is always possible, but more effort is required. Since dysphagia was not present before operation, it must be due to loss of the nerve supply to some muscle of deglutition. But since this disturbance was absent in five cases, one is led to wonder whether the muscles involved may not have a variable nerve supply. The table (group III) showing the muscles involved in deglutition and their nerve supply indicates that three of the infrahyoid muscles—sternohyoid, sternothyroid and omohyoid—partially lose their nerve supply by the operation. Each of these muscles also receives a partial nerve supply from the hypoglossal nerve, i. e., through the ansa hypoglossi, and this remains intact. The remaining infrahyoid muscle—the thyrohoid—is supplied exclusively by the hypoglossal nerve. The partial loss of the infrahyoid muscles leaves the many suprahyoid muscles, to a degree, unopposed. The varying degree of nerve supply to the

infrahyoid muscle, i. e., whether from the cervical or the hypoglossal nerves, probably explains the difference in results with respect to deglutition.

DIFFERENCE BETWEEN THE AUTHOR'S OPERATION AND THAT OF FINNEY AND HUGHSON

In the operation of Finney and Hughson, only the posterior divisions of the first three cervical nerves are divided, the anterior divisions being inaccessible. By their operation, therefore, the following muscles of rotation remain intact or in part as indicated: (1) rectus capitis lateralis; (2) rectus capitis anterior; (3) longus capitis; (4) sternomastoid (branches from the second and third cervicals); (5) trapezius (branch from the third cervical); (6) levator anguli scapulae (branch from the third cervical).

I am not sure that the muscles retained by their operation and sacrificed by mine will eventually make any difference in the ultimate result. It is my impression that the principal difference, if any, would lie in the partial preservation of function in the more powerful muscles, i. e., the sternomastoid, trapezius and levator anguli scapulae muscles.

SUMMARY AND CONCLUSIONS

1. An operative procedure is presented for treatment in spasmodic torticollis. The first, second and third sensory and motor roots on both sides are sectioned intradurally, and the spinal accessory nerves are divided peripherally, small incisions in the neck being used.

2. Eight patients have been operated on by this method with the following results: (*a*) five appear to be cured; (*b*) two are greatly improved but not cured; (*c*) one died of pneumonia (not contracted at the time of operation) three weeks after operation.

3. Torticollis is cured by removing the nerve supply from the major muscles of rotation. The remaining muscles will overcome in time and by training the lost motor function and in most instances any remaining traces of the condition.

NOTE.—Since this article was submitted for publication I have sectioned the upper three motor cervical nerves on both sides without sacrificing any sensory fibers. There was no difficulty in avoiding the sensory roots, and the preservation of sensation should make a worth while improvement in the procedure.

FORTY-FIRST REPORT OF PROGRESS IN ORTHOPEDIC SURGERY *

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CONGENITAL DEFORMITIES

Torticollis.—Von Lackum [1] advocated early operative treatment for torticollis and reported four cases in infants ranging in age from 5 weeks to 5 months in whom the scar of the belly of the sternomastoid was excised. None of the cases had responded to manipulative measures. The injury was found to be sharply limited within the sheath of the sternocleidomastoid muscle. No attempt was made to suture the ends of the muscle after excision of the scar.

Cleidocranial Dysostosis.—Fitchet [2] reported eight additional cases of this anomaly, six of which occurred in three generations of one family. The article furnishes an excellent review of the literature.

Congenital Dislocation of the Hip.—Putti [3] made a plea for earlier treatment in congenital dislocation of the hip. In certain parts of Italy,

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* This report is based on a review of 315 articles selected from 808 titles dealing with orthopedic surgery appearing in medical literature between June 1, 1929, and Nov. 30, 1929. Only those papers which seem to represent progress have been selected for note and comment.

1. Von Lackum, H. L.: Surg. Gynec. Obst. **48**:691 (May) 1929.
2. Fitchet, S. M.: J. Bone & Joint Surg. **11**:838 (Oct.) 1929.
3. Putti, V.: J. Bone & Joint Surg. **11**:798 (Oct.) 1929.

through educational propaganda, people bring their small children for examination on the slightest suggestion of an abnormality. In this way, many congenital dislocations are recognized during the first year. The roentgenogram at this age will show the nucleus of the upper femoral epiphysis absent or smaller on the dislocated side, the top of the femur some distance from the floor of the acetabulum and higher than normal and an increase in the slope of the acetabulum. If the legs of these small children are kept in a position which compels the femoral heads to exert pressure on the acetabula for several months, reduction of the dislocation and normal development of the joint will usually occur. The author devised a triangular wooden frame adjustable to different angles. To this the child's legs are strapped in the maximum amount of abduction and internal rotation. The frame is removed for bathing and manipulations in abduction and internal rotation. X-ray pictures are taken every two months. Treatment is discontinued when reduction is perfect and the reconstruction of the joint well advanced. Treatment usually lasts from eight to twelve months.

NUTRITIONAL AND METABOLIC DISTURBANCES OF BONE

Viosterol.—Smith and Elvove,[4] studying the effects of viosterol in rabbits, found doses of 2 mg. or more usually fatal, autopsy showing calcification of the aorta, kidney and lung. Smaller doses increased the blood serum calcium rapidly, and a moderate increase in the inorganic phosphates of the serum was observed.

Hess, Lewis and Rivkin[5] stated the belief that viosterol is a specific for rickets, tetany and osteomalacia. A standard dose has been established for the prevention and cure of rickets. Premature and exceptionally rapid growing infants must be regarded as a separate group, and dosage should be based on a biologic estimation of antirachitic potency rather than a gravimetric assay of the viosterol. Such products should be subjected to careful laboratory control.

An editorial[6] after pointing out the potency of this drug, quoted the warning of the United States Public Health investigators: "Of course we would not be understood as deprecating the therapeutic use of irradiated ergosterol, but would rather call attention to the possible harm that might result from too large doses."

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4. Smith, M. I., and Elvove, E.: Pub. Health Rep. **44**:1245 (May 24) 1929.

5. Hess, A. F.; Lewis, J. M., and Rivkin, H.: Status of Therapeutics of Irradiated Ergosterol, J. A. M. A. **93**:661 (Aug. 31) 1929.

6. Irradiated Ergosterol—A Reminder, editorial, J. A. M. A. **92**:2023 (June 15) 1929.

Parathyroids.—Richardson, Aub and Bauer [7] reported a case of apparent osteomalacia with aseptic cavities throughout the bones suggestive of osteitis fibrosa. The patient was a man, aged 34, who presented marked muscular weakness, gave a history of multiple fractures and presented x-ray pictures showing marked diminution of calcium throughout the skeleton. Studies of the calcium and phosphorus revealed: (1) markedly elevated serum calcium, (2) greatly increased calcium secretion, (3) reduced serum phosphorus and (4) increased phosphorus excretion. By removal of the parathyroid glands the patient was greatly benefited. His muscle tone improved; there was a greater increase in calcium deposit in the bones. He sustained no further fractures and was able to return to work. A review of the work on parathyroidectomy in conditions of calcium deficiency in bones is appended.

Experimental Acromegaly.—Teel and Watkins [8] noted a marked drop in the nonprotein nitrogen of the blood of dogs after injection of pituitary anterior lobe extract. They said that this effect may be one of mobilizing protein from the blood for the purpose of building up new protoplasm. This is in harmony with the pronounced rapidity with which many of the tissues and organs grow during acromegaly.

Osteitis Deformans.—Bascourret and Decourt,[9] studying ten cases of Paget's disease, found in each case, comparing the affected and the nonaffected limbs, differences suggesting changes in the sympathetic nervous system, increased local temperature, hyperpulsatility of the arteries, etc. From this they argued that the bony changes are due to disturbances in the trophic nerves, particularly the tractus intermediolateralis as in tabes.

SCOLIOSIS

In ankylosing the spine for scoliosis, Kleinberg [10] would employ as much as possible of the Hibbs technic but would add the massive tibial graft of Albee, placing it on the concave side. With a marked razorback deformity, resection of a portion of the involved ribs and the use of such ribs for a graft in fusion is a valuable procedure. Selection of the portion of the spine to be fused is important, and an attempt should be made to select the primary curve. At any rate, the dominant curve or the more deformed curve should be the one of choice. Ninety patients have been operated on by Kleinberg since 1919. The results in fifty-four of the cases are recorded. Forty-two or 78 per cent obtained excel-

7. Richardson, E. P.; Aub, J. C., and Bauer, W.: Ann. Surg. **90**:730 (Oct.) 1929.

8. Experimental Acromegaly, editorial, J. A. M. A. **93**:849 (Sept. 14) 1929.

9. Bascourret, M., and Decourt, J.: Rev. Neurol. **36**:606 (April) 1929.

10. Kleinberg, S.: J. Bone & Joint Surg. **11**:66 (Jan.) 1929.

lent results, i.e., arrest of deformity, satisfactory appearance of the back and relief from backache; 13 per cent had good results, i.e., good appearance of the back but slight or doubtful increase in the curve; 9 per cent were failures; i. e., there was a distinct increase in the deformity.

PAIN IN THE BACK, SCIATIC PAIN AND SPONDYLITIS

Lumbosacral Deformities.—A study of 3,000 radiograms formed the basis for this essay for which Brailsford [11] received the Robert Jones medal and the British Orthopaedic Association's prize for 1927. The deformities in this area of the spine are grouped by Brailsford under the following headings: (1) congenital abnormalities, (2) injury, (3) inflammation, (4) neoplasms and (5) disease of bone of uncertain origin.

Congenital abnormalities were present in 26 per cent, often giving rise to no symptoms or signs, and detectable only by roentgen examination. The most frequent deformity associated with developmental irregularity was scoliosis due to asymmetrical sacralization of the fifth lumbar vertebra. Sacralization of the fifth lumbar vertebra was found in 8.1 per cent (3.4 per cent unilateral, 4.7 per cent bilateral) of the cases. Ossification of the iliolumbar ligaments might occur and was usually associated with pain. Arthritic changes and osteophytic outgrowths encroaching on the nerve foramina were often present in irregular and asymmetrical joints. The articular facets of the fifth lumbar were directed in many ways—57 per cent backward, 12 per cent inward, and in 31 per cent mixed, facing in different directions on the two sides.

Five examples of spondylolisthesis were found in the series. Brailsford expressed the belief that this condition is frequently erroneously diagnosed, and he expressed doubt concerning the possibility of manipulative reduction. Both anteroposterior and lateral views are needed for one to be certain of the diagnosis; either by itself may mislead. None of the five patients complained of pain in the back, and in four there was no pain. The gait of two was normal, of two it was waddling, and the fifth had a marked limp. With regard to injury, severe trauma can occur in the lumbosacral region without producing a spondylolisthesis. Lipping of the margins of the vertebral bodies and calcification of the connecting ligaments were occasionally seen as a sequel of an injury which had apparently not caused any bony damage. Fracture of a transverse process might easily be erroneously diagnosed from the roentgenogram. In osteo-arthritis lipping of the border of the bodies was common, but Brailsford, contrary to Putti, concluded that the articular surfaces were usually smooth and presented no irregularities. Spondylolisthesis was not a common sequel of tuberculosis of the lumbosacral

11. Brailsford, J. F.: Brit. J. Surg. **16**:562 (April) 1929.

region; on the contrary, the lumbar lordosis was usually lost, the sacrum flat and the lumbosacral angle obliterated. Two examples of gummas of the vertebrae were noted. Brailsford relied for the diagnosis on the large amount of symptomless destruction with sclerosis and on the overgrowth of the bone around.

[ED. NOTE.—In the interpretation of roentgenograms of the lumbosacral region, this paper is valuable as a reference. An extensive bibliography is given.]

Hibbs and Swift [12] reported their results in 150 cases of lumbosacral fusion, in the majority of which one of the following conditions was present: (1) an unusually acute lumbosacral junction, (2) spondylolisthesis, (3) sacralization of one or both transverse processes and (4) incomplete fusion between the first and the second sacral vertebrae. They stated that 73.3 per cent of their patients were entirely relieved; 14 per cent were improved, and 12.7 per cent were unimproved.

Mueller [13] demonstrated several cases of spondylolisthesis which, according to the patients, have been caused by traumatism. He said that he regards this as incorrect, claiming that the condition is congenital in nature or exists from early youth. From a study of x-ray pictures, the inclination of the sacrum averaged 67.5 degrees in persons standing. This, however, had nothing to do with the development of spondylolisthesis. Children with bilateral congenital dislocation of the hips often had a certain degree of spondylolisthesis.

Ayers [14] expressed the belief that the cause of pain in the lower part of the back with sciatica is a disturbance at the lumbosacral junction and not in the sacro-iliac region. His analysis of the anatomic distribution of pain in these cases (buttock, posterolateral thigh and calf and outer side of ankle) is that it is distributed along the course of the fourth and fifth lumbar and first sacral nerves, which he stated do not come in relation to the sacro-iliac joints. He also stressed the observation of Wilson and Danforth that the fifth lumbar nerve root, while being the largest lumbar branch, has the smallest exit from the vertebral canal. Many of the x-ray pictures in his cases showed an arthritis of the facets at the lumbosacral junction, a thinning of the cartilage or rarely, spondylolisthesis. For treatment in this condition, he advised immobilization by the Hibbs method of fusion. Thirty-six cases in which fusion was done are reported.

Arthritis.—Gunther and Sampson [15] stated the belief that precordial pain from osteo-arthritis of the spine is distinguished by its close relation

12. Hibbs, R. A., and Swift, W. E.: Surg. Gynec. Obst. **48**:604 (May) 1929.

13. Mueller, W.: Zentralbl. f. Chir. **57**:234, 1930.

14. Ayers, C. E.: New England J. Med. **200**:592 (March 21) 1929.

15. Gunther, L., and Sampson, J. J.: Radicular Syndrome in Hypertrophic Ostearthritis of Spine, J. A. M. A. **93**:514 (Aug. 17) 1929.

to motion of the spine and that relief is afforded by mechanical appliances and a nonresistant surface for sleeping. Associated sensory changes are often present. This type of pain does not respond to vasodilators.

TUBERCULOSIS

Potts' Disease.—Sorrel [16] resumed the results of his researches on the mechanism, the signs and the prognosis in Potts' paraplegia. If one eliminates the paraplegias from osseus compressions which are exceptional, one may consider two varieties of paraplegia, that caused by abscess and that caused by pachymeningitis. The paraplegias caused by abscess occur early, usually toward the end of the first year, and rapidly become complete. They have a tendency toward spontaneous regression in 90 per cent of the cases. They are by far the more frequent. The paraplegias caused by pachymeningitis are late, often occurring in old cases of Potts' disease which are irregularly healed. They develop slowly, often remaining incomplete, and while they seem less grave, they are more severe, having no tendency toward regression. Sorrel's opinion is that any surgical treatment, spinal graft or laminectomy can influence to an appreciable degree the natural evolution of these paraplegias, favorable in the first type and unfavorable in the second.

[ED. NOTE.—This is an excellent summary of the situation and well worth quoting to all students.]

Tuberculosis of the Joints.—Girdlestone [17] stated his indications for open operation, as part of the treatment, in tuberculosis of the larger joints. In adults, operation should be the rule as soon as the general condition of the patient is on the mend. In children, operation is indicated whenever sufficient damage has been done to the joint to make movement incompatible with permanent safety from relapse; but the operation should not be undertaken until after one year of nonoperative treatment and not before the child has reached the age of 10. The type of operation advocated varies with the different joints: for sacro-iliac disease, Verrall's extra-articular arthrodesis; for disease of the hip, extra-articular arthrodesis, with excision in addition when massive granulation tissue is present; for tuberculosis of the knee, partial excision and arthrodesis; for tuberculosis of the shoulder, excision and arthrodesis. This author does not favor operations on the elbow, and is doubtful about the advisability of operating on the ankle. Amputation is indicated in many patients beyond middle age. For secondarily infected joints, he advocates the preliminary removal of sepsis by wide drainage opera-

1929.

16. Sorrel, E.: Bull. et mém. Soc. nat. de chir. de Paris **55**:658 (May 18)
17. Girdlestone, G. R.: Brit. M. J. **2**:529 (Sept. 21) 1929.

tions. Girdlestone emphasizes the fact that operation is not a substitute for, but an adjunct to, nonoperative treatment.

Tuberculosis of the Hip.—Pattison [18] recorded the immediate results in 300 cases of tuberculosis of the hip joint. The diagnosis was made by clinical observation, but care was taken to exclude all cases in which the patients were suffering from some obvious condition, such as coxa vara, pseudocoxalgia or pyogenic arthritis. Also, all cases of transient arthritis in which the condition cleared up within a month were excluded. His results were as follows: (1) cured (perfect movement, no shortening, no sign of disease), 167 or 55 per cent; (2) arrested (diminution of movement, shortening deformity), 97 or 32 per cent; (3) relapse, 28 or 9 per cent; and (4) dead or dying, 13 or 4 per cent.

[ED. NOTE.—Pattison is working at a county hospital and treats his patients with recumbency and traction. But we do not believe any one will accept the statement that all of the 55 per cent of patients who were cured had suffered from tuberculous disease of the hip.]

Tuberculosis of the Knee.—Pouzet,[19] in the service of Professor Nove-Josserand, studied juxta-articular tuberculosis in twenty-five old cases in children; of these, thirteen had femoral and twelve tibial lesions. He came to the following conclusions: 1. Such lesions may heal by conservative measures, but the treatment is long and the results uncertain. 2. By excising these lesions the duration of treatment is reduced two-thirds, and the removal of the focus renders the cure more certain. It is necessary always to immobilize after the operation until the cure is complete. 3. The indications for the operation depend on the age (before 5 or 6 years), the possibility of surrounding the lesion and the condition of the joint. 4. As to the disturbance in growth, the author stated that this is due to the destruction of the epiphyseal cartilage and does not depend on the method of treatment.

Lance [20] discussed the use of a bone graft of the knee after the manner of Lexer. It consists of a transfixion by an autogenous graft without actually opening the joint. The principal indication, according to the author, is the incomplete and painful ankylosis which follows a tuberculosis of the knee in childhood. It is less mutilating than a resection, at the same time acting as an arthrodesis. It should be used in cases in which there is shortening. If there is shortening, the fixation should be in extension; if there is no shortening, it should be ankylosed in some flexion. In active cases the danger of establishing a sinus is overbalanced by the advantages of the operation. In the author's cases, how-

18. Pattison, C. L.: Brit. M. J. **2**:532 (Sept. 21) 1929.

19. Pouzet, F.: Rev. d'orthop. **16**:297 (July) 1929.

20. Lance, M.: Bull. et mém. Soc. nat. de chir. de Paris **55**:626 (May 11) 1929.

ever, the patients did not do so well when there was activity. He therefore regards the procedure as more suitable for old inactive but painful cases.

[ED. NOTE.—Pouzet's procedure may be sound for small foci, but we doubt the possibility of successfully excising tuberculous foci when we must depend on the x-ray picture to determine the extent of such foci. In our experience, the disease may have spread so far beyond the apparent focus that definite limits can not be found. With the method described by Lance, we have no experience. Erasion or fusion operations seem to offer a more certain means of obtaining satisfactory fixation.]

POLIOMYELITIS

Aycock,[21] in a study of the seasonal and climatic fluctuations in the incidence of infection from poliomyelitis, reached the conclusion that these fluctuations are due to changes in the resistance of the subject. He does not consider the dose or the virulence of the virus as important factors. As evidence for postulating such geographic and seasonal variations in the subject's resistance or "autarcesis," as he terms it, the author cited seasonal variations in growth and changes in weight of various organs with different seasons and climates. Such changes, in his opinion, produce a physiologic imbalance, making the subject less resistant to the virus.

Aycock and others [22] reported the results of treatment with convalescent serum in 116 cases of preparalytic poliomyelitis in Massachusetts during 1928. The results were more carefully controlled than in the patients treated at Haverhill, Mass., in 1927. A striking decrease is shown in the mortality and amount of paralysis in the treated patients as contrasted with the untreated ones. This cannot be measured readily in percentages.

McEachern [23] and his co-workers reported their results in administering poliomyelitis convalescent serum during the Manitoba epidemic in 1928; seventy-four of 161 patients received this serum. Fifty-four received no serum and thirty-three received it after the onset of paralysis. Of fifty-seven patients receiving an average of 25 cc. of the serum intramuscularly in the preparalytic state, 93 per cent recovered, and there were no deaths. Of the fifty-four patients receiving no serum, 26 per cent recovered, 11 per cent died and the remainder were paralyzed. They

21. Aycock, W. L.: J. Prev. Med. **3**:245 (May) 1929.

22. Aycock, W. L., et al.: Preparalytic Poliomyelitis, J. Infect. Dis. **45**:175 (Sept.) 1929.

23. McEachern, J. M., et al.: Canad. M. A. J. **20**:368 (April) 1929.

concluded that convalescent serum was of value when given during the preparalytic stage, and that the intramuscular route was safe and efficacious.

Diveley [24] studied 185 cases of poliomyelitis developing during an epidemic in Kansas. Eighty-five of the cases were carefully followed by the author for two years. He concluded that by early drainage of the spinal canal and intravenous or intramuscular administration of immunized horse serum, or better, antipoliomyelitic (human convalescent) serum, many dire results can be prevented. Also careful treatment during the second stage of the disease will diminish immeasurably (90 per cent) the resulting deformities. He substantiated his observations with experimental work on monkeys.

Rhoads [25] injected intracerebrally into a monkey the virus of poliomyelitis which had been preserved in glycerol eight years. Eight days later there were marked symptoms of extensive involvement of the central nervous system. The animal was killed the following day, and marked degeneration of the anterior horn cells was demonstrated. The virus from the first monkey was passed through four other monkeys in succession, and in all the disease developed without the virus losing any of its potency. The longevity of the virus suggests to Rhoads the improbability of the streptococci as the inciting organism in the disease.

Stewart and Rhoads [26] inoculated eight monkeys intradermally with repeated small doses of living, active poliomyelitis virus. A second group of eight monkeys were given repeated small inoculations of the same virus subcutaneously. The period of immunization lasted from three to five months. During this period no signs suggesting poliomyelitis were found. The monkeys were bled, and the neutralizing power of the serum on poliomyelitis virus was noted. Subsequently, the monkeys were given intracerebral injections of poliomyelitis virus. The serums of all the monkeys, with the exception of one in which subcutaneous injection had been attempted, completely neutralized the virus. The degree of immunity was only relative, since one case immunized intradermally and four of the cases immunized subcutaneously exhibited definite poliomyelitis. The authors stated the belief that a greater degree of immunity is conferred by intradermal than by subcutaneous injections.

PYOGENIC INFECTIONS

Phemister,[27] in discussing chronic fibrous osteomyelitis, described the roentgenologic and microscopic appearance of such lesions in the early,

24. Diveley, R. L.: J. Bone & Joint Surg. **11**:100 (Jan.) 1929.
25. Rhoads, C. P.: J. Exper. Med. **49**:701 (April) 1929.
26. Stewart, F. W., and Rhoads, C. P.: J. Exper. Med. **49**:959 (June 1) 1929.
27. Phemister, D. B.: Ann. Surg. **90**:756 (Oct.) 1929.

intermediate and late stages. He pointed out that during the first few months while the disease is progressive, the cavity is filled with soft, grayish or brown tissue and that microscopically it consists of fibroblasts, capillaries, polyblasts, giant cells and blood pigment. There is usually some necrosis about the cavity, and cholesterol slits are sometimes seen. The response about the fusion is variable, for a little or a great deal of new bone may be laid down. After a period of months or years the disease may come to a standstill, and the cavity may be partially or wholly filled with connective tissue or bone trabeculae bearing much resemblance to a benign giant cell tumor or an osteitis cystica.

These cases are usually not seen until they have been in progress for several months, because they are relatively symptomless. The organism is usually of low virulence. Eleven cases have been studied by Phemister, and he reported six of these.

ARTHRITIS

Current comment in the *Journal of the American Medical Association* [28] says that Poston [29] after the lapse of fifteen years during which he used the same technic as Rosenow, has isolated organisms from the glands removed from patients with infectious arthritis. She obtained growths from 72 of 120 glands, and 93 per cent of the organisms isolated were *Streptococcus viridans*. The similarity between the results of the pioneer work and those of the recent work will be of interest to the many physicians who at present are devoting their attention to the problems of arthritis.

An editorial in the *Journal of the American Medical Association* [30] says that Cecil and his co-workers strongly favor the view that chronic infectious arthritis is a streptococcal infection, caused, in a large proportion of cases, by a biologically specific strain of this organism. The demonstrated presence of this specific strain of streptococcus in the blood of several patients with advanced arthritis deformans goes far to corroborate the view already widely held that arthritis deformans and chronic infectious arthritis are one and the same disease. Whether the demonstrated micro-organisms act further, as some physicians believe, to exert an indirect physiologic influence through action on the endocrine systems remains far more problematic.

The results may indicate that etiologically there are at least two types of chronic arthritis: that which is a true specific infection char-

28. Cultures of Lymph Nodes in Arthritis, current comment, J. A. M. A. **93**: 1313 (Oct. 26) 1929.

29. Poston, M. A.: Gland Cultures in Infectious Arthritis, J. A. M. A. **93**: 692 (Aug. 31) 1929.

30. Chronic Infectious Arthritis, editorial, J. A. M. A. **93**:284 (July 27) 1929.

acterized at times by a bacteremia, and that which either is not of bacterial nature or does not have periods of bacteremia. These fall, respectively, into the present pathologic types of atrophic or infectious arthritis, on the one hand, and hypertrophic arthritis, on the other.

Cecil and his co-workers [31] reported the results of a series of blood and synovial fluid or membrane cultures in chronic arthritis. Blood cultures were obtained from seventy-eight patients. In forty-eight of these a streptococcus was found. There appeared to be a higher percentage of blood cultures in patients more than 50 and in those who had had the disease a number of years. In six cases cultures were made from synovial membrane; in one case culture was made from the synovial fluid. In five of these seven cases a bacterium was isolated; four showed a streptococcus. Eleven rabbits were given intravenous injections of these cultures; seven developed arthritis, but only after repeated injections.

[ED. NOTE.—These editorials show the strong trend toward a bacterial cause for all infectious arthritis. We doubt if the differentiation is as cleancut as the editorial would lead us to believe.]

NEOPLASMS

Bucy [32] described the pathologic observations in seven cases of hemangioma of bone. Usually there is a hard swelling of bone over the area of the hemangioma. Microscopically, a vascular tissue is found, usually soft, often of jelly-like consistency. It consists of large cavernous spaces containing blood cells and lined by a single layer, usually of flat endothelium. There is a loose connective tissue stroma. The surrounding bony trabeculae show degenerative and formative changes which are probably secondary reactive phenomena. There is no microscopic evidence of a malignant condition. These growths may be called neoplasms or vascular malformations. The author can suggest no etiology from this study.

CIRCULATORY AND NERVE DISTURBANCES

Barron and Linenthal [33] concluded from their observations on thirty-four cases of thrombo-angiitis obliterans, twenty-seven of which had come under their personal observation, that the disease is apt to be more generalized than commonly supposed, and that it may affect the vessels of the brain, heart and abdomen as well as those of the extremities.

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31. Cecil, R. L.; Nicholls, E. E., and Stainsby, W. J.: Bacteriology of Blood and Joints in Chronic Infectious Arthritis, Arch. Int. Med. **43**:571 (May) 1929.

32. Bucy, P. C.: Am. J. Path. **5**:381 (July) 1929.

33. Barron, M. E., and Linenthal, H.: Thrombo-Angiitis Obliterans, Arch. Surg. **19**:735 (Oct.) 1929.

Many of their patients, although they were all well under 50 years of age, suffered from hemiplegia, coronary disease or severe abdominal pain from arterial occlusion before or after the disease had manifest itself in the extremities. They believed that the disease is slow in onset, that the occlusion is primarily an inflammatory affair and that as it is developing there is opportunity for development of collateral circulation.

Kornblum [34] discussed the roentgen observations in the bones of the extremities in patients suffering from Raynaud's disease. The first changes are those of atrophy of bone in the affected phalanges with a gradual disappearance of the distal end of the phalanx. If the disease progresses, the entire phalanx may disappear. With recovery from the disease, there is disappearance of atrophy of the bone, and the phalanges again become visible in the roentgenograms. These changes have been observed in other conditions and are in no way pathognomonic of Raynaud's disease, but the author believes that they are evidence of tissue starvation from inadequate blood supply.

Two cases of loose intervertebral cartilage were reported by Dandy.[35] Both occurred in the lumbar region and followed rather mild trauma. Both cases presented marked symptoms of cord compression with extensive paralyses and loss of sphincter control. In both the roentgenogram was negative. In both the fragment of the cartilage was found lying loosely between the third and the fourth vertebral bodies and was pushing directly back against the dura. In each case the fragment was easily removed, and in each case recovery was progressive, although somewhat slow in the second case because of the relatively long duration of symptoms.

[ED. NOTE.—The rupture of intervertebral disks has been described before, but we feel that it is altogether probable that such a condition may exist more often than we are able to discover.]

SPINAL FUSION OPERATIONS IN THE TREATMENT FOR PAIN IN THE LOWER PART OF THE BACK AND FOR SCIATIC PAIN

A study was made by Chandler [36] of twenty-nine patients with pain in the lower part of the back and with sciatic pain on whom various types of spinal fusion operation had been performed. In eleven of the patients the fusion was of the lumbosacral region of the spine, and in one additional case the right sacro-iliac joint was fused at the same time. In the remaining seventeen patients, the author's operation of trisacral fusion

34. Kornblum, K.: Am. J. Roentgenol. **21**:448, 1929.

35. Dandy, W. E.: Loose Cartilage from Intervertebral Disk Simulating Tumor of Spinal Cord, Arch. Surg. **19**:660 (Oct.) 1929.

36. Chandler, F. A.: Spinal Fusion Operations in Treatment of Low Back and Sciatic Pain, J. A. M. A. **93**:1447 (Nov. 9) 1929.

of the lumbosacral and both sacro-iliac joints had been done. In nine cases the results were entirely satisfactory to the patients, but could not be rated as more than good because of some discomfort on certain motions of the spine. Two patients showing generalized arthritic changes obtained fair relief. Two patients showed no improvement in symptoms after lumbosacral fusion, and their cases were considered failures. Fifteen patients reported complete relief from symptoms, and the results were considered excellent from the standpoint of both the patient and the surgeon. In regard to symptoms before operation, the author stated that in general the objective manifestations of the pain in the lower part of the back were such as to indicate disease of the various elements of the spine and pelvis but lacked the clearcut differential features so frequently found in acute lesions of this region. Roentgenologic considerations were of the highest importance when interpreted in conjunction with the history and physical examination in determining the operation.

Phelps and Lindsay [37] reported that they had employed with success a slight modification of Verral's method of extra-articular fusion of both sacro-iliac joints in three patients. All obtained relief from their symptoms and were back at work within a year of their operation. The operation consisted in passing a bone graft which was removed from the tibia transversely through drill holes which were made in either posterior superior spine and through the spinous processes of the sacrum.

[ED. NOTE.—Chandler's report is of considerable interest and shows the feasibility of relieving many patients with obstinate pain in the back by fusion operations. At the same time it is to be noted that results which could be rated as really excellent were obtained in only fifteen of twenty-nine cases, although improvement was noted in others. This would seem to argue for the need of careful study, accurate diagnosis and extreme conservatism before resorting to operation.]

Operative Correction of Coxa Vara.—Heydemann [38] described the operative procedures that were employed for the treatment of coxa vara in Gocht's clinic in Berlin. In patients with mild deformities, simple subtrochanteric osteotomy was considered sufficient. In cases of severe deformity, a cuneiform osteotomy was performed between the trochanters. The upper limb of the wedge was made in the direction of the axis of the neck of the femur. The size of the wedge to be removed was determined beforehand by careful measurement on the roentgenogram. The lower limb of the osteotomy was therefore made in accordance with these measurements. The inner cortical surface of the bone

37. Phelps, W. M., and Lindsay, M. K.: Surg. Gynec. Obst. **49**:555 (Oct.) 1929.

38. Heydemann, H.: Klin. Wchnschr. **7**:2250 (Nov. 18) 1928.

was not cut but left to be fractured when the osteotomized surfaces were approximated. Position was maintained by the application of plaster of paris spica casings. The advantages of the method were that the correction was made close to the seat of deformity, that it did not involve the joint, that damage to muscles was avoided and that the wide bony surfaces could be readily approximated. The results had been excellent in the patients treated; the gait had been improved, and Trendelenburg's phenomenon had disappeared.

Osteoplastic Surgical Exposure of the Ankle Joint.—Koenig and Schaefer [39] described a method of surgical approach to the ankle joint which had proved useful in their hands. A convex incision with its base downward was made over the internal malleolus. With an osteotome the malleolus was divided at its base, the deltoid ligament being preserved intact. It was then possible to dislocate the astragalus outward with the malleolus and expose the joint surfaces. In closing the incision, the malleolus was replaced and fixed with a nail. The method was suitable for fracture dislocations of the astragalus and other traumatic conditions and also for arthrodesis.

[ED. NOTE.—This method of approach seems neat and under certain conditions ought to be useful.]

Arthrodesis of the Ankle Joint.—Campbell [40] described the operative procedure he employed to secure osseous fusion of the ankle joint and reported the results obtained in three patients with tuberculosis and one with arthritis. Instead of denuding the cartilage from the articular surfaces of the ankle joint, he preferred to fuse the joint by making anterior and posterior incisions through which osteoperiosteal grafts were slid downward from the tibia into the denuded neck of the astragalus and upward from the os calcis into the denuded posterior borders of the astragalus and tibia. A plaster casing was worn for three months, followed later by a brace which was worn until the fusion was solid.

FRACTURES

General.—Ashhurst,[41] in discussing the question of whether accurate reduction of fracture is necessary, stated that generally speaking much less accurate reduction is necessary in children than in adults. Fractures into or near joints should always be replaced as accurately as possible. He said, further, that too much damage was frequently done to soft parts in attempting to secure accurate reduction of fractures of the shafts of bones; that in such fractures, if bony union was obtained

39. Koenig, F., and Schaefer, P.: Ztschr. f. Chir. **215**:196, 1929.
40. Campbell, W. C.: Am. J. Surg. **6**:588 (May) 1929.
41. Ashhurst, A. P. C.: Ann. Surg. **90**:556 (Oct.) 1929.

and the axis of the fragment preserved, and if there was shortening of not more than 1 cm., the result was usually satisfactory.

Stating his views on the operative treatment of fractures of the long bones, Scudder [42] enumerated the types of fractures which should frequently or always be treated by open reduction and described under what conditions such a procedure should be undertaken. He stated further that the ultimate aim in the treatment of any fracture should be a good functional result; that at times the anatomic result might be fair or poor yet the function of the joints good. Nevertheless, unless conditions contraindicate it, a perfect anatomic result should be striven for irrespective of whether it could be gained by closed or open methods.

Darrach [43] listed the dangers from the operative treatment for fractures as follows: (1) infection; (2) hemorrhage, immediate or remote; (3) vascular interference resulting in delayed healing or nonunion; (4) faulty material—poor plaster of paris bandages, defective plates or screws or weak suture material; (5) delayed decision, i.e., operative treatment as a last resort and (6) faulty judgment.

Fracture of the Internal Epicondyle of the Humerus with Displacement into the Elbow Joint.—Cotton [44] reported three instances of avulsion of the epiphysis of the internal epicondyle complicating dislocations of the elbow in which disturbance of the motor and sensory function of the ulnar nerve followed attempts at reduction. In each of the cases the fragment of bone was found lying in the elbow joint, and tight bands of fascia from the displaced epiphysis were found pulling on the ulnar nerve. The treatment consisted in removal of the displaced fragment and release from tension on the ulnar nerve. Practically complete restoration of nerve function resulted in all cases. The author stated that he had seen twelve instances of this injury.

Brentnall [45] reported the operative results in two patients who had sustained fractures of the internal epicondyle of the humerus with displacement of the fragment into the elbow joint where it blocked movement. Both cases were unusual, because there was no associated lesion of the ulnar nerve, and the elbow had not been dislocated. This was contrary to the views of Cotton and of Fairbank, both of whom believed that the displacement of the epicondyle was due to the manipulation of a dislocated elbow in the attempt to secure reduction. Brentnall suggested that the injury was caused by an abduction strain and was in reality a rupture of the internal lateral ligament of the elbow.

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42. Scudder, C. L.: Ann. Surg. **90**:589 (Oct.) 1929.
43. Darrach, W.: Ann. Surg. **90**:595 (Oct.) 1929.
44. Cotton, F. J.: J. Bone & Joint Surg. **11**:348 (April) 1929.
45. Brentnall, E. S.: Brit. M. J. **1**:1113 (June 22) 1929.

Lesions of the Ulnar Nerve in Injuries of the Wrist.—In a group of 500 cases of injuries of the wrists, R. Watson Jones [46] found only three instances of palsy of the ulnar nerve. In one the injury was an outward dislocation of the wrist with a marginal fracture of the radius, and the palsy was due to traction on the nerve. The other two were due to contusion of the nerve; in the first the injury was a displacement of the radial epiphysis backward and outward with a radio-ulnar dislocation, and the nerve was impaled on the lower end of the diaphysis of the radius, which had gone forward and inward. In the second, the injury was an unreduced severe Colles' fracture, five weeks old; the nerve was impaled on the lower end of the upper fragment of the radius. The patients in all three cases recovered after reduction of the dislocations.

Position in the Treatment for Fracture of the Carpal Scaphoid.—Berlin [47] made an anatomic study of the scaphoid bone, dissecting sixty wrists in order to determine what was the best position in which to treat fractures of the scaphoid. He found that the major portion of the ligamentous structure springing from the dorsal carpal ligament gained insertion on the proximal two thirds of the dorsal surface of the scaphoid bone. Since the dorsal carpal ligament was placed under tension with the hand in flexion the scaphoid ligamentous slip springing from it was likewise rendered taut and pulled the proximal fragment away from the distal one.

The approximation of the broken fragments was distinctly favored by the tendons of the flexor carpi radialis and the flexor pollicis longus. They acted together as a sling to the scaphoid bone on its volar surface when the hand was placed in extension.

The small lateral interosseous ligament in the proximal row of carpal bones was placed under tension when the hand was flexed to either side and in a minor degree displaced the fragment by tending to produce lateral angulation.

The radial collateral ligament stretching from the radial styloid to the tubercle of the scaphoid, by the nature of its attachment favored better alinement of fragments when the hand was extended to the radial side.

The position of choice in the treatment for carpal scaphoid fractures was about 45 degrees extension of the wrist with radial deviation avoiding extreme or forced extension.

[ED. NOTE.—Berlin's observations confirm what had already been established by clinical results that a position of moderate dorsiflexion of the wrist gives the best approximation of fragments in scaphoid fractures.]

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46. Jones, R. Watson: Proc. Roy. Soc. Med. **22**:1071 (June) 1929.
47. Berlin, D.: New England J. Med. **201**:574 (Sept. 19) 1929.

Fracture Dislocations of the Cervical Spine.—Three instances of fracture of the atlas were reported by McWhorter,[48] all occurring in adult males. In two of the patients the injury was produced by a fall on the head; in the third case the patient was struck by an automobile. In only one patient was the atlas alone involved. In this case the ununited posterior arch was removed three months after injury to relieve a severe occipital neuralgia. Complete recovery followed the operation. The author reviewed the literature.

Taylor[49] discussed fracture dislocations of the cervical vertebrae, particularly those produced by indirect violence and dealt with the methods of production and the various types of injury that might be sustained by the cord, the spinal nerves and the cervical spine and its supporting structures. He advised manual traction under a general anesthetic as a means of reducing the fracture dislocation followed by the application of a plaster jacket with a head piece to be worn for several weeks—followed later by physiotherapy. Illustrative cases were appended.

Vertebral Fractures Without Spinal Deformity and Without Lesions of the Spinal Cord.—Huet[50] made a comprehensive study of vertebral fractures without associated lesions of the spinal cord. He pointed out their great frequency and the difficulty of recognizing them from clinical signs alone. The traumatism was often slight. A fall or blow on the head or the neck usually caused cervical injuries, while fractures of the lower lumbar region resulted most commonly from falls on the feet or on the ischia in the sitting position. The dorsal region of the spine was better protected by reason of the greater strength of the anterior common ligament at this level, and this explained the relatively lesser frequency of injuries here.

Displacement of the fragments might be almost nil but in the majority of cases was more or less marked. Usually it was produced immediately at the moment of injury, but it might occur secondarily during transportation or late as in the case of the progressive displacement observed in patients with unrecognized and untreated fractures. A long period was required for the production of firm bony callus, and hence prolonged immobilization in good position was necessary to prevent increase in the bony deformity.

From the standpoint of industrial and legal medicine, it had to be recognized that the period of temporary disability was of long duration; in the case of cervical injuries, Stempel and Boekel estimated it at about one year. Even though this might seem long to insurance companies, it

48. McWhorter, G. L.: J. Bone & Joint Surg. **11**:286 (April) 1929.
49. Taylor, A. S.: Ann. Surg. **90**:321 (Sept.) 1929.
50. Huet, M. P.: J. de chir. **34**:15 (July) 1929.

was to their interest not to attempt to shorten it. Insufficient treatment was likely to be followed by unpleasant sequelae, such as crumpling of the vertebral body, development of exostoses, delayed involvement of the cord, paralysis, etc. The disability that resulted even in cases of slight fracture due to complaint of pain was not less than 10 per cent and more often was from 20 to 40 per cent and even higher.

Discussing the relations between these lesions and Kummel-Verneuil's disease, the author expressed the opinion that Kummel's syndrome did not exist. In France, the case described by Robineau in which the integrity of the vertebra had been shown by a roentgenogram made immediately after the injury, remained unique.

[ED. NOTE.—This article is of value in recording French opinion on the subject of vertebral fractures.]

Injuries Complicating Fractures of the Pelvis.—Wakeley [51] recorded the complications associated with 100 nonfatal cases of fractures of the pelvis. Of these, only eleven were complicated by visceral injuries: six, rupture of the urethra; four, extraperitoneal rupture of the bladder and one, intraperitoneal rupture of the bladder. In no nonfatal case was the rectum injured. All these complications were associated with "run-over" accidents; nonfatal accidents, the result of direct trauma and of crushing forces were not complicated by visceral injuries. There was no case of injury to the sacral nerves at the time of the injury, and only one at a later date, following a fracture of the sacrum, and due possibly to compression from excessive callus formation.

Perforating Fractures of the Acetabulum.—Cottalorda [52] made a study of perforating fractures of the acetabulum, basing his conclusions on a review of the literature and an analysis of one hundred and seven reported and unreported cases. The injury was encountered most commonly in men between the ages of 20 and 40 years. In the majority of cases it was caused by a fall on the lateral surface of the greater trochanter, the hip being in a position of extension and of extreme internal rotation. The author reviewed the symptomatology and pointed out that rectal examination rarely gave clear information as to the nature of the injury in spite of the fact that it was generally considered to be pathognomonic. He recognized three types of deformity: fractures without penetration, fractures with partial penetration and fractures with complete penetration.

Regarding the fracture from the industrial point of view he distinguished on a clinical basis three types of old fracture: first, the pseudo-coxalgic type; second, the dystocic or obstetric type; and third, the progressive type in which the protrusion of the femoral head into the

51. Wakeley, C. P. G.: Brit. J. Surg. **17**:22 (July) 1929.
52. Cottalorda, J.: Presse méd. **37**:388 (March 23) 1929.

pelvis begins and increases progressively by reason of premature use. It happened, however, even with a marked penetration of the femoral head that the patient sometimes developed an adaptation to the condition and was able to take up his former employment. The most common complications were rupture of the bladder and urethra, hematoma under the psoas muscle and stubborn neuralgias.

The prognosis was the more serious the greater the degree of penetration of the head. Twenty-seven of eighty-six patients were reported as cured (31.3 per cent), twenty-four or 27.9 per cent died, and in thirty-five or 40.6 per cent varying degrees of ankylosis developed. The percentage of disability was estimated at between 30 and 40 per cent, and the average period of time required for consolidation was six months.

Treatment for Fractures of the Leg by Delbet's Plaster Splint.—Crossan [53] advocated the use of the Delbet plaster splint for the treatment for fractures of the middle and lower thirds of the leg and reported the results of such treatment. In ninety-nine patients with such fractures admitted to Ashburt's service at the Episcopal Hospital in Philadelphia between October, 1922 and October, 1927, all but thirty-three were treated by this method. Fifty-two of these patients were traced and a study of the end-result obtained. Forty-three, or 83 per cent, showed a good anatomic result: 13 per cent a fair and 4 per cent a poor result. The function in forty-four cases, or 85 per cent, was good; in 11 per cent fair and in 4 per cent poor.

The materials necessary and their application to make the Delbet splint were described. It was applied while continuous traction over the end of the table was maintained. The patient was made to walk in ten days with crutches, and in six weeks the plaster was removed.

DISLOCATIONS

Dislocations of Semilunar Bone.—Discussing dislocations of the carpal semilunar bone, Watson-Jones [46] analyzed the end-results in twelve patients whom he had treated. In two, this bone was excised, giving a 75 per cent return of function; in the third, the semilunar and half the scaphoid were excised, with a 50 per cent return of function. Six patients were seen within a few days of the injury, and the dislocation was reduced by closed manipulation, with a 100 per cent return of function.

Watson-Jones described his method of closed reduction as follows:

> The patient's wrist was fully dorsiflexed, the thumb of one hand was placed anteriorly over the dislocated bone to steady it and to prevent it rotating forward.

53. Crossan, E. T.: Delbet Apparatus and End-Results, Arch. Surg. **19**:712 (Oct.) 1929.

With the other hand the manipulator gripped the patient round the fingers, exerted strong traction, and pulled the os magnum away from the radius. Whilst exerting this traction the hand was slowly palmar flexed, the os magnum was gradually pulled round the back of the semilunar until its head glided into the cup of the bone.

This maneuver was unsuccessful when injuries were more than four days old, and for those Watson-Jones advocated open reduction; through a 3 inch dorsal incision, the head of the os magnum was freed from the adhesions which had formed between it and the capsule and the remaining bones; then the same manœuver was employed as in the closed method of reduction to secure replacement. Watson-Jones was strongly opposed to the method of reduction in which the semilunar is pried back into position by means of bone levers.

Three patients on whom open reduction by the author's method had been done were back at work: one as a ship's riveter, another as a sailor and the third as a railway engine driver.

Watson-Jones thought that closed reduction should be attempted up to the end of a week after the injury, open reduction thereafter and excision not unless the injury was of more than three months' duration.

Utilization of Long Tendon of Biceps to Prevent Recurrent Dislocation of the Shoulder.—Nicola [54] described a new operation for recurrent dislocation of the shoulder in which he utilized the long tendon of the biceps muscle to serve as a check ligament. He divided the tendon 1½ inches (3.8 cm.) above the point where it dipped down to pass under the pectoralis major muscle, freed the proximal end well up into the bicipital groove and passed it through a tunnel drilled in the head of the humerus to be resutured at the point where it emerged to the divided distal end of the tendon. The arm with the elbow flexed to an angle of 45 degrees was bandaged to the side for three weeks, after which active use was permitted.

Reduction of Dislocations of the Hip Under Nerve Block Anesthesia.—Mueller [55] stated that he had found that manipulative reduction of traumatic dislocations of the hip, which was always difficult under general anesthesia, was greatly facilitated by nerve block anesthesia. He had employed paravertebral nerve block of the first to the fourth lumbar roots and infiltration of the sciatic nerve. He had used it in four cases with complete success. In one of the patients reduction had been tried under general anesthesia by three different surgeons the day previously. In another patient the reduction was accomplished almost spontaneously, after anesthesia had been secured, by turning the patient from the prone into the supine position.

54. Nicola, T.: Am. J. Surg. **6**:815 (June) 1929.

55. Mueller, W.: Zentralbl. f. Chir. **57**:224, 1930.

The author had likewise made use of nerve block of the brachial plexus in cases of dislocation of the humerus. Here too he had found that reduction was made remarkably easy.

[ED. NOTE.—The muscular relaxation obtained by nerve block is more complete than with general anesthesia, and thus the muscular resistance which has to be overcome in securing reduction is diminished or eliminated. There would seem to be a real advantage in the method, particularly in dislocation of the hip.]

RESEARCH

Influence of Irradiation on the Resistance to Infection.—With a view to determining the influence of irradiation on resistance to infection, Eidinow [56] carried out experiments on animals. He irradiated a group of rabbits with his special lamp (emitting infra-red, luminous and ultra-violet rays up to 2,850 angström units) continuously for forty-eight hours, and then inoculated them intravenously with a broth culture of virulent staphylococci. The control animals died within twenty-four hours of the inoculation, while four of the thirty irradiated animals recovered, and the remaining twenty-six survived for an average of seven days. Eidinow was unable to discover the mechanism of the increased resistance. Experiments indicated that the irradiation increased the hemobactericidal power but not in proportion to the general increased resistance to infection. It did not raise the rectal temperature.

The Intra-Articular Pressure and Absorbing Power of Joints.—Rostock,[57] using a manometer, measured the intra-articular pressure in knee joints following injuries with effusion of blood. In some instances he found pressures as high as 700 mm. of water. The amount of intra-articular pressure was not directly proportionate to the amount of the effusion. The pressure was greatest immediately after the injury and diminished in time. As a result of his studies, Rostock was impressed with the importance of evacuating fluid as early as possible with the view of lessening the damage to the joint. Even when the fluid was not entirely removed, aspiration lessened the intra-articular pressure, and hence reduced the danger of chronicity. Measurements of the pressure in joints with septic arthritis showed particularly high readings.

The same author [58] also studied the absorbing power of the knee joint in more than 100 patients with different disease conditions. He injected a known quantity of sodium iodide solution, and then measured the amount of iodine excreted in the urine during a given time. He found that the rate, amount and duration of the absorption varied

56. Eidinow, A.: Brit. M. J. **2**:293 (Aug. 17) 1929.
57. Rostock, P.: Deutsche Ztschr. f. Chir. **213**:314, 1929.
58. Rostock, P.: Deutsche Ztschr. f. Chir. **215**:76, 1929.

markedly in different diseases and under different conditions. In septic arthritis the absorption was rapid and of large amount, especially during the first hour following injection. The absorption when infection was absent was far less rapid. The rate of absorption in traumatic conditions with hemarthrosis varied with the duration of the condition; it was most rapid when the injury was recent. A slow beginning and a long duration were noted in chronic hydrops. Because of the sluggish rate in chronic joint conditions, Rostock considered it advisable to perform arthrotomy with the purpose of creating an acute condition and thus speeding absorption.

[ED. NOTE.—Rostock's experiments are of interest as tending to shed further light on the physiology of joints under diseased conditions. Further studies under normal and abnormal conditions will be necessary before their true significance can be appraised.]

Experimental Arthritis.—Key [59] studied the reaction of the knee joints in rabbits to single and repeated injections of citrated blood and to single injections of india ink. The cells were studied by fixed smears and by vital staining methods, followed at the end of twelve days by microscopic study of the joint tissues. A single injection of citrated blood produced a cellular exudate, which disappeared in about twelve days. During the first two days, leukocytes were the predominating cells; later, macrophages predominated. The only change in the exudate with repeated injections was an increase in the number and size of the macrophages. With injections of india ink, the exudate contained many leukocytes and macrophages throughout the twelve day period. The majority of the macrophages were monocytes. Some red blood cells in the exudate were carried away by clasmatocytes; others were entangled in fibrin clots which became organized and covered by synovial lining cells. Most of the india ink was removed by macrophages and leukocytes; some was organized in fibrin clots and covered by synovial lining cells. With single injections of india ink or citrated blood there was a mild proliferation of the surface cells and infiltration of the subsynovial tissues with leukocytes and macrophages. With repeated injections of blood, the synovial membrane was markedly thickened. No observations were made after the twelfth day. At this time the tissues showed a partial return to the normal condition.

Experiments with Foreign Materials to Stimulate Epiphyseal Growth of Long Bones.—Bohlman [60] reported experiments performed with foreign materials in the region of the epiphyseal cartilage plate to stimulate longitudinal growth of bones. Pegs of various metals, wood, ivory,

59. Key, J. A.: J. Bone & Joint Surg. **11**:705 (Oct.) 1929.
60. Bohlman, H. R.: J. Bone & Joint Surg. **11**:365 (April) 1929.

autogenous bone, insoluble salts, essential oils and vaccines were used as foreign materials. The author concluded that there was no increased growth in length of bone in any of the animals. In many cases, a marked shortening resulted.

The Vessel Canals in Normal Bone.—From the studies of the development of the vessel canals Joffe [61] pointed out that in fetal bone the vessels grew in from the periosteum. The spaces between the periosteal trabeculae constituted the primary haversian systems. In early infancy canals were present in the cortex and connected the haversian canals and the marrow cavity. In the epiphyses canals were present which disappeared as cartilage was replaced by bone. By the eleventh year the adult vessel pattern was found. Before this age there were reconstructions of the vessels in the bone, old ones being obliterated and new ones laid down. The haversian canals ran longitudinally. Those nearer the surface communicated with canals of the ground lamellae, which in turn anastomosed with periosteal vessels. The Volkmann's canals were formed by canalization of fully developed bone by new vessels which entered the bone at various angles to its long axis.

MISCELLANEOUS

Disease of the Temperomandibular Joint.—One of the chief obstacles to the diagnosis of and treatment for lesions of the temperomandibular joint is the difficulty of showing the region clearly in the roentgenograms. Bishop [62] made a study of the normal and pathologic anatomy of this articulation and of its varying appearance in the roentgenogram. He described a method of making a roentgen examination of the joint which minimized distortion and ought to lead to more accurate diagnosis.

Wakeley [63] reported his operative observations on two patients with displacement of the mandibular cartilage. In both the cartilage preserved only its anterior attachment, the posterior attachment having been torn. Both patients complained of an audible click on mastication. In one the symptoms followed a violent fit of coughing and in the other the extraction of a tooth under anesthesia. The click disappeared after the removal of the cartilage.

Fixed Obliquity of the Pelvis.—Mayer [64] stated that fixed obliquity of the pelvis might result from: (1) contraction of the hip abductors on one side; (2) contraction of the hip abductors on one side combined with contraction of the adductors on the opposite hip; (3) a combina-

61. Joffe, H. L.: Am. J. Path. **5**:323 (May) 1929.
62. Bishop, P. A.: Am. J. Roentgenol. **21**:556 (June) 1929.
63. Wakeley, C. P.: Lancet **2**:543 (Sept. 14) 1929.
64. Mayer, L.: Am. J. Surg. **6**:804 (June) 1929.

tion of the first and second plus contracture of the spinal muscles producing fixed deformity of the lumbar spine.

In recent cases traction might suffice to correct the deformity. In cases of long standing, operative treatment was necessary. This consisted of complete division of the tensor fascia femoris and abduction of the muscles and of the capsule of the hip joint through a lateral incision. To maintain the hip in adduction, a strip of fascia lata was freed above the knee and dissected upward to a point midway between the hip and knee and then carried subcutaneously over the anterior thigh and sewed to the pubic spine. It might be necessary to divide the adductors of the opposite hip and if the spinal muscles were contracted, traction ought to be applied to the spine.

[ED. NOTE.—Fixed obliquity of the pelvis is a troublesome problem, and in our experience has not been especially helped by the usual methods of scoliotic correction. Mayer's method sounds radical, but we shall watch his results with interest.]

Morbus Coxae Senilis.—Kienböck [65] explained the development of deforming osteo-arthritis of the hip on the basis of a presenile trophostatic change in the structures composing the joint. The primary changes were caused by nutritive disturbance, and secondary static changes then occurred. The initial signs shown by roentgen examination were depression of the acetabular roof and elongation of the lateral rim. With this there would be noticed a certain amount of osteoporosis. The primary changes did not occur in the head but in the acetabulum. The condition might remain stationary at this state or progress with the development of the characteristic deformity. He distinguished a primary and secondary type, the latter being the result of earlier lesions of the hip, such as accidents or Calvé-Legg-Perthe's disease.

Intrapelvic Protrusion of the Acetabulum.—Doub [66] reported eight cases of intrapelvic protrusion of the acetabulum. It was bilateral in five cases and unilateral in three. The duration of symptoms was from one to seven years, with an average of three and one half years. Clinically, the most common observation was restriction or absence of abduction of the leg, and next was restriction of flexion and hyperextension. The ages varied from 16 to 53. The roentgenograms showed a deepening of the acetabulum with thinning of the mesial and inferior wall. The head of the femur was, therefore, more deeply buried, and the greater trochanter was somewhat higher and closer to the ilium. As to the etiology, he suggested that the condition could best be explained by some general disease in early life causing softening of the bones with resulting deformity, and that the osteo-arthritis so often found was a later stage in the process.

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65. Kienböck, R.: Med. Klin. **25**:817 (May 24) 1929; **25**:860 (May 31) 1929.
66. Doub, H. P.: Radiology **12**:369 (May) 1929.

A Study in Fitting the Ring of the Thomas Splint.—Those interested in the careful fitting of Thomas splints would do well to consult Young's [67] recent article which was based on a study of the living subject and of the cadaver. He concluded that the shape of the ring, its size, padding and other characteristics depended on the purpose for which the splint was to be used. The shape and angle should differ, depending on whether the patient is recumbent or ambulatory or whether the hip is flexed much or little or is in a position of extension.

Cysts of the Semilunar Cartilages.—The literature accumulating on cysts of the semilunar cartilages of the knee was further enriched by Ollerenshaw's [68] report of eighteen additional cases. Of these, four were in connection with the internal cartilage. The author reaffirmed his belief that the cysts were of developmental origin. The pathologic histology was described and illustrated by several excellent photomicrographs.

Pes Valgus Staticus.—Boehm [69] has continued his studies of the development of deformities of the knee and foot, comparing the conditions found with certain stages of the development of the lower extremities in the human embryo. His theories in regard to the development of clubfoot have been previously described. On the basis of additional observations he recently reported finding similar relationships in respect to pes valgus staticus, meaning that form of pronated foot which is generally first noticed during the years of puberty and which has generally been explained on the basis of faulty statics. He found that the embryonic foot at a certain stage in its development showed certain similarities to the pronated foot of adolescence, especially in the relations between the axes of the tibioastragalar and subastragalar joints. This relation was different from that seen in the normal and rachitic pronated foot. This difference was shown by illustrations of the specimens. Boehm concluded that the occurrence of pes valgus staticus could be explained on the basis of an arrested development with permanent alteration of the planes of the articular surfaces.

Steindler,[70] studying the mechanics of pes valgus, observed that in most cases of nonrigid flatfoot there was a compensatory supination of the forefoot. This he explained as due to the necessity of securing plane contact of the entire forefoot with the floor. When the posterior portion of the foot was in a valgus position, a supination of the forefoot had to occur at the midtarsal joint to permit weight-bearing over the

67. Young, C. S.: Study in Fitting Ring of Thomas Splint, J. A. M. A. **93**:602 (Aug. 24) 1929.

68. Ollerenshaw, R.: Brit. J. Surg. **16**:555 (April) 1929.

69. Boehm, M.: Ztschr. f. orthop. Chir. **52**:424, 1929.

70. Steindler, A.: J. Bone & Joint Surg. **11**:272 (April) 1929.

entire forefoot. He believed that in order to rebalance the foot it was necessary to insert not only a pronatory wedge under the inner side of the heel, but also a supinatory outer wedge under the little toe.

Traumatic Subastragalar Arthropathy.—O'Connor [71] described a condition affecting the subastragalar joint following trauma, but without any demonstrable fracture, which he called traumatic subastragalar arthropathy. He had observed the condition in five patients. There was a history of long-continued pain and disability. In one patient subastragalar arthrodesis was performed with relief from symptoms. The symptoms consisted of pain in the heel on weight-bearing and inability to walk on rough ground without pain. On examination tenderness was found on pressure along the medial, lateral or both aspects of the subastragalar joint and pain in the subastragalar joint on hammer percussion over the heel or on attempting to rise on the ball of the foot or on lateral movement of the foot. He did not believe that the prognosis for recovery without pain was good under conservative treatment and expressed the opinion that subastragalar arthrodesis was indicated if the pain persisted after three months.

SURGICAL INTERVENTION IN DISEASES OF THE TENDONS, BONES AND JOINTS

Present Status of Synovectomy.—Analyzing the present status of the operation of synovectomy, Swett [72] expressed the opinion that it has a definite place in certain cases of chronic infectious arthritis, particularly of the knee. The operation should be performed only after the elimination of foci of infection and the establishment of a good state of nutrition. In the patients on whom he had performed the operation there had been a good immediate response, but in several there had later been a relapse and subsequent involvement of other joints.

[ED. NOTE.—We agree that synovectomy of the knee has a place, but rather a limited place, in surgical treatment for chronic arthritis. It is particularly beneficial in the patients with chronic hydrops. Its effects are much more local than general.]

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71. O'Connor, D. S.: New England J. Med. **200**:987 (May 9) 1929.
72. Swett, P. P.: Am. J. Surg. **6**:807 (June) 1929.

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